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(MANTECH) PROGRAM

Statistical and Economic Evaluation of the Bearing Maintenance Capability and Assets at Corpus Christi Army Depot

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FINAL REPORT

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This report covers work performed under contract DAAG48-81-C-0004, "Statistical and Economic Evaluation of the Bearing Maintenance Capability and Assets at Corpus Christi Army Depot." The purpose of this program was to:

Provide statistical and economic evaluation of bearing maintenance capability and assets at Corpus Christi Army Depot.

Investigate the feasibility of establishing an improved CCAD Refurbishment Center.

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This program was accomplished by reviewing CCAD's bearing inventory and cost, inspection procedures, analyzing current and new approaches of bearing refurbishing and estimating the number of bearings suitable for CCAD refurbishment.

On conclusion of the review and analysis, specific recommendations were provided for improving CCAD's bearing refurbishment techniques.

PREFACE

This final summary report describes the results and recommendations of a Manufacturing Methods and Technology program conducted by Mechanical Technology Incorporated to perform a statistical and economic evaluation of bearing maintenance capability and assets at Corpus Christi Army Depot.

This project was accomplished as part of the US Army Aviation Research and Development Command Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel. Comments are solicited on the potential utilization of the information contained herein as applied to present and/or future production programs. Such comments should be sent to: US Army Aviation Research and Development Command, ATTN: DRDAV-EGX, 4300 Goodfellow Blvd., St. Louis, MO 63120.

EXECUTIVE SUMMARY

Escalating inflation, uncertain delivery schedules and a general shortage of alloying materials have serious implications with respect to both readiness and the economics facing most overhaul depots. This is particularly true of the bearings removed from overhauled aircraft. A three-phase program was formulated to address the bearing problem.

Phase I - Quantify the problem and establish economic justification.

Phase II - Develop improved methods for inventory control; critically evaluate procedures and standards for bearing processing; supply and install diagnostic equipment; train personnel in its use; and set operational criteria for refurbishment of bearings.

Phase III - Expand the bearing refurbishment activity; generate new expansion plans; define, procure, and install new equipment determined by the outcome of Phase I; train personnel; and initiate and supervise operation until satisfactory results have been achieved.

The work described herein represents results of the first phase of the proposed three-phase program which, when implemented, should contribute to a significant decrease in bearing problems currently facing most overhaul depots.

The Bearing Shop at Corpus Christi Army Depot (CCAD) is one of the largest of its kind in the country, annually processing about 200,000 bearings that encompass about 400 different parts numbers per year. Of this number, approximately 143,000 bearings come from overhauled aircraft, and the remaining 57,000 are procured to replace normal rejects encountered at overhaul. It is clear that the current facility is frequently overburdened. Processing a quantity this great creates a situation in which bearings that normally could be passed during a normal inspection have to be filed into a special storage area because the inspector lacks the time to thoroughly

examine them. Close to 36,000 reasonably expensive bearings found their way into this storage area by the end of 1980.

Most of these bearings could be refurbished and put back into use, producing substantial savings to the Government in the process and alleviating the critical bearing storage situation. Enough work has been performed to prove that it is feasible to regrind bearings, both from an economical as well as from a practical standpoint. In fact, theoretical studies as well as practical tests performed by NASA indicate that close to 90% of all the bearings reaching a Bearing Shop such as CCAD's could be saved by expanding the bearing restoration operations to cover more extensive rework such as grinding and matching of the reground bearings with new rolling elements of larger size. This has been common practice with the commercial airlines.

The implementation of an expanded refurbishment program will require the addition of new machinery and new diagnostic equipment. In order to raise the overall quality level of new and refurbished bearings, more reliable diagnostic techniques will have to be applied. These techniques should be based upon new equipment developed within the past decade which utilizes the state of the art in the fields of electronics and microprocessors.

Analysis of the refurbishment needs of the CCAD Bearing Shop included consideration of bearing criticality in terms of applications and lead times, and segmentation of the bearings stored in the Automatic Storage and Retrieval System (ASTORS). Following an assessment of the economic benefit of refurbishment, 22 bearing types were identified as sufficiently critical, in widespread use, and high in unit cost to justify further attention.

For such bearings, a generic refurbishment system was outlined and may be characterized as follows. The bearing diagnostic subsystem envisioned here is an adaptation of the Mechanical Technology Incorporated (MTI) bearing diagnostic equipment (known as the BDI-100) and a companion piece of equipment, the Asperitac™. Modification of this equipment is needed in order to accommodate different bearing types without disrupting the process flow. The overhaul and rework subsystem contains grinding and plating equipment to permit major refurbishment of a bearing. An inventory management subsystem

is also included to provide an effective management tool for controlling both the Bearing Shop (viewing it as a factory) and the total bearing inventory.

The system was considered in three levels of equipment redundancy:

- Baseline System - Consists of one element of each piece of equipment required in a bearing refurbishment system
- Economics System - Contains enough redundant equipment to accommodate the workflow associated with the 22 critical bearing types
- Readiness System - Contains additional redundancies and other supporting equipment to extend readiness via increases in responsiveness, throughput, reliability and quality.

Both recurring and nonrecurring costs for these three alternatives have been approximated together with the potential savings made possible by reducing the number of replacement bearings that must be purchased. The savings are partly based on the refurbishment of the expensive bearings in the temporary ASTORS storage, but benefits derived from the inventory management subsystem are not included.

An analysis of the economics of each system reveals that all yield net savings over a five-year period. The economics system is most attractive, offering a payback in 24 months. Using a 10% discount rate to put monetary value on the timing of the cash flow, the economics system has a net present worth of $6.2 million for a 10-year period of operation following 4 years of program study and implementation. For this period, the internal rate of return is about 36%. An annual unit refurbishment cost of $207, which is 54% of the average cost of the replacement bearings, reinforces the financial attractiveness of the economics system.

Recommendations include a phased implementation of the economics system with several of the key options from the readiness system so that the role of the Bearing Refurbishment System can be enhanced in a timely and economical way.

In summary, the potential for improvement exists in the areas of economics and readiness. The economic opportunities include: (1) the savings possible by refurbishing bearings rather than replacing them and (2) the economics offered by the ability to control costs more effectively, both in the process area and in the purchasing area, with modern management information systems. Readiness can be enhanced by increased responsiveness and more reliable, higher quality products. MTI feels that these potential improvements can be achieved using a system which is modular, reliable, and as independent as readiness goals can justify.

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ACKNOWLEDGEMENTS

Mechanical Technology Incorporated (MTI) and TRW Bearing Division wish to acknowledge the excellent cooperation received from the Directorate of Maintenance at Corpus Christi Army Depot (CCAD). Particular thanks also are due to Mr. Don Wells, Chief of Production Engineering Division, and Mr. Moheb Asaad, production engineer and point of contact on this program. The assistance and cooperation received from the crew of the CCAD Bearing Shop is also deeply appreciated.

The work described in this report represents contributions from R. Craig (MTI), C. Hand (MTI), E. Koch (MTI), H. Munson (TRW), J. Wagner (MTI), and L. Winn (MTI), the program manager.

1.0 INTRODUCTION

This program was carried out under Contract No. DAAG-48-81-R-001, issued by Corpus Christi Army Depot with the objective of performing the statistical and economic evaluation of a bearing maintenance capability and assets at the Corpus Christi Army Depot (CCAD). Mechanical Technology Incorporated (MTI) and TRW Bearing Division (formerly MRC) have jointly carried out the contractural commitments. The results of this work indicate that substantial savings can be accrued through the introduction of modern and improved bearing diagnostic techniques, expansion of the currently employed bearing restoration processes, and improvements in the inventory management procedures. The implementation of the proposed recommendations have become almost mandatory due to escalating inflation, uncertain delivery schedules, and a general shortage of alloying materials.

The work described in this report represents results of the first phase of the proposed three-phase program which, when implemented, should contribute to a significant decrease in bearing problems currently facing most overhaul depots. The second phase of this program, when approved, will concentrate on the development of improved methods for inventory control, critical evaluation of procedures and standards for bearing processing, supply and installation of diagnostic equipment, training personnel in its use, and setting operational criteria for restoration of bearings. It will be necessary for the Contractors to provide supervision and training for CCAD personnel over the first six months of system operation. The third phase, which could be carried out concurrently with Phase II, will concentrate primarily on the aspects of bearing refurbishment. The scope of Phase III is to expand the bearing refurbishment activity; generate new expansion plans; define, procure, and install new equipment determined by the outcome of Phase I; train personnel; and initiate and supervise operation until satisfactory results have been achieved.

The economic analysis performed within the scope of Phase I provides ample justification for the expansion of CCAD's bearing diagnostics and refurbishment capabilities. In addition to dollar savings, such expansion should:

- Contribute to the elimination of stock-piled "Cause for Reject" (CRF) bearings
- Increase the inventory of usable bearings required to supply normal overhaul
- Provide an inventory capable of supporting potential critical bearing shortages
- Expand the in-house bearing refurbishment capability
- Provide reliable and repeatable bearing diagnostic systems
- Help to relieve the shortage of critical alloying materials.

All these benefits will significantly contribute to the enhancement of the U.S. Army's strategic position while paving the way towards modernization of critical inspection areas.

It is recognized that the programs recommended in this report will not provide a complete solution to the problem of demand and supply currently in existence. In addition to the facility expansions suggested in this report, other means, such as subcontracting the rework of large critical bearings and expanding the qualified supply sources, should be investigated.

2.0 DEVELOPMENTS IN BEARING REFURBISHMENT TECHNOLOGY

2.1 Introduction and Terminology

Inspection and selection of usable bearings as well as various degrees of bearing refurbishment have been practiced for over 20 years. In this discussion, the terminology employed will identify the various bearing refurbishment requirements. The term "processing of bearings" will be used to denote checking and inspecting a bearing against specified drawing requirements or service wear limits. The processing of bearings consists primarily of three stages:

- Preparatory. Demagnetization and cleaning.
- Comparative Inspection. Nondestructive testing (NDT), visual/microscopic inspection, and dimensional examination.
- Final Disposition. Lubricating/preserving, and packaging according to predetermined standards.

"Refurbishment of bearings" encompasses general work to be performed on the bearing to render it suitable for further use.

"Reconditioning of bearings" shall describe those procedures and operations that do not significantly change the dimensions and/or geometry of the ball or roller raceway. The procedures and operations encompass buffing, and polishing of the inner and outer ring raceways of rolling element bearings, and the use of new rolling elements and/or cages in conjunction with acceptable bearing inner and outer races. Minor repairs to the inner diameter (I.D.) and outer diameter (O.D.) of the bearing rings (such as polishing to remove temperature discoloration due to oxide formation and stubborn products of oil decomposition) also represent a form of refurbishment.

The term "bearing rework" shall encompass a number of major operations. Bearings subjected to rework may require one or more of the following: honing or regrinding of the inner or outer races; replating of either the inner ring bore, outer ring bore, or guiding lands; regrinding of the replated surfaces or of the critical sides of the bearing rings; destructive removal of cage,

replacement of cage; replacement of rolling elements oversized to account for the increase in the internal bearing clearance.

"Used Bearings" are bearings removed from inspection during scheduled TBO's (Time Before Overhaul) or unscheduled removals.

"New Bearings" are bearings procured either normally through supply channels, directly from local distributors, or through transfer of stock by inter-service agreements.

"ASTORS" denotes an Automatic Storage and Retrieval System in existence at CCAD to temporarily store bearings which (1) do not fully meet inspection criteria, and (2) do possess potential for salvage through rework.

A significant degree of bearing reconditioning is currently being practiced at CCAD. Rework of bearings, however, is nearly nonexistent at this time.

In general, the implementation of bearing reconditioning requires neither unusual skill nor sophisticated machinery. Nevertheless, depending upon the final application, substantial attention may have to be devoted to the inspection process to assure that the bearings, either directly reused or refurbished, will not contribute to the degradation in life of the given piece of parent machinery.

A summary of the current state of the art of bearing refurbishment technology is given in the following subsections.

2.2 Bearing Refurbishment

2.2.1 Commercial Airlines

Commercial airlines have refurbished many of their engine, transmission, accessory, and airframe bearings. The latest estimates of the savings accrued by the commercial airlines are not available, but as of 1976, one major airline alone refurbished or sent for refurbishment close to 2,400 jet engine main shaft bearings and up to 12,000 accessory bearings per year. At that time it was estimated that the savings arising from this refurbishing process amounted to $1,000,000 annually [1]*

2.2.2 TRW Bearings Division

At TRW Bearings Division, refurbishment of bearings is performed within the Special Products Group in its Falconer, New York Super Precision Bearing Plant. This activity developed from the fact that many aircraft bearings are found to deviate slightly from specifications when removed from an engine during scheduled overhaul, and are thus unacceptable for return to service. Approval was obtained from the FAA and engine manufacturers to repair such bearings and reuse them, based on the amount and type of deviation and operating experience in the application.

TRW is currently refurbishing main shaft engine bearings for many airlines, including American Airlines, Delta Airlines, Eastern Airlines, Northwest Orient, Pacific Southwest, TWA, Air Canada, Japan Airlines, and Lufthansa.

TRW Bearings Division is approved as a repair station by the FAA. Bearings are refurbished in accordance with standards established by engine manufacturers.

Table 2-1 lists those bearings refurbished and shipped by TRW in 1979.

Most of the bearings refurbished in TRW's Special Products Group were removed from Pratt & Whitney engines in commercial airplanes. TRW currently has a contract with Kelly Air Force Base to refurbish bearings from military aircraft; these involve bearings from General Electric engines.

*Numbers in brackets indicate references found in Section 9.0.

TABLE 2-1

BEARINGS REFURBISHED AND SHIPPED BY TRW IN 1979

ENGINE	POSITION	NUMBER OF BEARINGS	BEARING DESCRIPTION
PWA JT8D	#2	106	100mm bore duplexed ball bearings
	#3	106	110mm bore ball bearing
	#4	126	125mm bore ball bearing
PWA JT9D	#2	86	220mm bore ball bearing
	#4	46	165mm bore roller bearing
PWA JT3D	#2	112	130mm bore ball bearing
	#4	32	140mm bore duplexed ball bearings
	#4½	1	100mm bore roller bearing
	#6	44	70mm bore roller bearing

All bearings which are refurbished in TRW's Special Products Group were originally manufactured by TRW.

Customer-owned bearings not made by TRW have been reworked on a limited basis by TRW to new specifications. This practice is not defined as refurbishment.

TRW's bearing refurbishment involves the following operations:

- Bearing disassembly
- Visual inspection
- Dimensional inspection
- Stripping of silver plate from cages to facilitate inspection
- Honing of raceways
- Replacement of rolling elements
- Replacement of inner races if the used races are damaged beyond the capability of honing to repair
- Replacement of cages if necessary
- Magnetic particle and nital etch inspection of new inner races
- Fluroescent penetrant inspection of cages, both used and new
- Silver plating of cages
- Balancing of cages
- Correcting face flushness or duplex on ball bearings
- Reassembly of bearings, bending lugs or riveting as required
- Reinspecting, preserving, packaging, and shipment.

If an outer race is not refurbishable by honing, the whole bearing is considered not restorable and is shipped back to the customer for disposition.

The capability of a bearing manufacturer to replace damaged components with new must be considered when determining whether a facility should restore bearings in-house or should contract the work to vendors.

TRW's refurbishment provides an economically viable alternative to the purchase of new bearings, with the price for refurbishing not exceeding 55% of the price of new bearings.

TRW is also able to rework bearings by regrinding races, by chrome plating and regrinding bores and O.D.'s, and by installing additional design features. Such work is expensive and is done due to limitations or for experimental designs.

2.2.3 DOD Experience

Various branches of the Department of Defense are also involved in bearing refurbishment, and progress has been made at many bearing rework facilities toward reducing bearing rejects through bearing refurbishment. The Corpus Christi Army Depot utilizes existing procedures and inspection equipment for processing directly reusable bearings and for refurbishing bearings with minor blemishes. CCAD is also continuously striving to improve its repair record through the introduction of new and modern inspection equipment, as well as bearing processing machinery. The Naval Air Rework Facility at North Island has been very active in the direction of bearing reclamation. This facility processes both large (i.e., main shaft engine bearings, transmission bearings, etc.) and small instrument bearings. The reclamation process has progressed to the point that some limited in-house grinding is performed. The more complex surfaces, however, are reground at qualified commercial facilities.

Recent attention has been given to the refurbishment of large bearings of different types at the Naval Air Rework Facility at Cherry Point. Some refurbishment is also going on at the Naval Air Rework Facility in Norfolk, and additional work is taking place at Naval Air Rework Facilities in Jacksonville, Pensacola, and Alameda.

The Tinker Air Force Base has been working on the improvement of their bearing reconditioning and restoration throughput. Currently, bearings are disassembled and the races examined. Serviceable races are reused, others are discarded; the usable races are then vibration cleaned and reassembled with new rolling elements, retainers, and rivets. The advanced type of engine at Tinker Air Force Base must be handled with great care and, consequently, the specifications guiding refurbishment and/or rework of these bearings are still somewhat controversial.

The bearing refurbishment activity that takes place within the various Defense Department establishments, however, falls short of the achievable goals and is limited when compared with the activities at commercial airlines and with the optimum bearing restoration potential defined by various investigators [1,2,3].

2.3 Current Bearing Refurbishing Activities at Corpus Christi Army Depot

Corpus Christi Army Depot handles maintenance on several U.S. Army helicopters, including the UH-1, AH-1, AH-1T, OH-58, OH-6A, and CH-47 models. This maintenance includes complete teardown, cleaning, inspection, replacement of damaged or limited-life parts, and reassembly, at specified operational times.

To accomplish this function, CCAD has set up a number of work areas, each having responsibility for a particular major subassembly function:

- engine
- transmission
- accessory gearboxes
- rotor head
- rotating electrical
- instruments
- hydraulic
- airframe
- wheels.

These work areas receive major components from the initial teardown of the helicopter and disassemble them into parts for cleaning, inspection, repair, etc. Ultimately, the major components are reassembled, using cleaned and inspected or repaired or new parts.

A major activity at CCAD is the processing of rolling element bearings used in these helicopters. CCAD has set up a special facility, the Bearing Shop, to clean, inspect, and make major repairs to bearings. A Standing Operating Procedure (SOP 700-3-M-1) has been established to define and direct this bearing processing. This procedure is shown in Appendix A.*

The Bearing Shop is responsible for providing ready-for-use bearings to the component reassembly areas both to meet production schedules and to maintain a 15-day supply. These bearings are obtained by passing or repairing bearings received from disassembly areas and by ordering new bearings from Supply. All bearings, both new and used, which enter the Bearing Shop are inspected. The Bearing Shop also processes used helicopter bearings from other Army depots, as well as limited number of Army tank bearings.

Currently the Bearing Shop processes about 200,000 bearings, encompassing about 400 different part numbers per year. Of this number, approximately 143,000 bearings come from overhauled aircraft. The remaining 57,000 are new bearings, procured to replace rejects and to provide a back-up inventory. These figures differ from year to year.

Of the used bearings processed through the Shop, the rejection rate averages at 30%. The reject rate of new bearings is about 0.5%. This indicates that 70% of used bearings are currently reprocessed and reused at CCAD. This number, however, could be increased to nearly 90% based on commercial airline experience [1]. Such an increase in acceptable used bearings could produce substantial savings.

A detailed description of the existing CCAD Bearing Shop, including equipment, processing, cleaning, and packaging procedures currently in effect, is provided in Appendix B.*

*Appendices are found in Volume II.

2.4 Technical Limitations to Bearing Rework

The rework of bearings requires insight into the theoretical and practical aspects of bearing design, manufacture, and operation if success is to be assured [4,5]. As will be shown in this subsection, limitations do exist which must be properly identified and defined prior to the commitment of a bearing to the process of rework. Particularly, the grinding process, whenever employed, mu . be carefully examined for each specific bearing size and type, and proper limits must be imposed on the amount of material to be removed. These limits will subsequently form part of an overall specification.

2.4.1 Theoretical Aspects

Until the beginning of World War II, the design and application of rolling elem'nt bearings could be considered more of an art than a science. In 1945, a more scientific approach was taken to the design of rolling element bearings, and scientific progress has continued at an exponential pace. The first quasi-scientific book entitled Ball and Roller Bearing Engineering was authored by Palmgren in 1945. The roller element bearing theory was further developed by Palmgren and Lundberg [6,7,8] and refined by A.B. Jones [9]. Most of the solutions to the design of rolling element bearings had been based on static or quasi-static conditions. Lately, Dr. P. Gupta of MTI has developed a comprehensive, fully dynamic computer code which, for the first time, recognizes the presence of a cage within a bearing and accounts for all the forces, static and dynamic, present in a bearing during operation.

Perhaps the most important theoretical parameter to be considered in bearing refurbishment and restoration is the bearing life. Because of the presence of cyclic stresses in the Hertzian contact areas between the rolling elements and races, and because of random inclusion and flow distribution in the structure of the material, the bearing life is subject to a statistical dispersion.

Fatigue in rolling element bearings has been generally categorized into two types:

- Surface-originated fatigue
- Subsurface-originated fatigue.

Surface fatigue normally originates at microcracks left on the race and/or rolling element surface either as a result of previous use or following the manufacturing process. Also, metallic interactions (in the case of very rough or starved contacts) which produce surface shear stresses have a dominant effect on surface-originated fatigue. If the surface roughness is controlled to be much less than the expected lubricant film thickness and if the manufacturing process is controlled to have minimal surface fatigue origination sites, then the surface fatigue phenomenon can also be greatly minimized. In the case of used bearings, refurbishing the race and rolling element surfaces may greatly improve the surface-originated fatigue life.

The most classical type of fatigue originates below the surface, at the point of the maximum sheer stress. The subsurface stress distribution for a pure normal load on the surface in a line contact configuration is shown in Figure 2-1. The maximum shear stress can be calculated using the Mohr circle at each point. The point contact solutions will be similar, but the depth and magnitude of the maximum shear stress will depend on the size of the contact zone (the semi-major and minor axes a and b, as shown in Figure 2-2. Thus, for a pure line contact ($b/a=0$), the point of maximum shear stress, Z_1, is about 0.78b and the value of the maximum shear stress is about 0.3 σ_{max}, σ_{max} being the maximum Hertzian contact stress. This will be true for roller bearings. For ball bearings, b/a is about 0.20 in a large number of applications and, therefore, Z_1 of about 0.74b and maximum shear stress of about 0.325 σ_{max} may be expected.

With this background on subsurface stresses, the probability of survival, S, of a rolling contact, is generally written as

$$\ell n \frac{1}{S} \sim f(\tau_o, N, Z) V$$

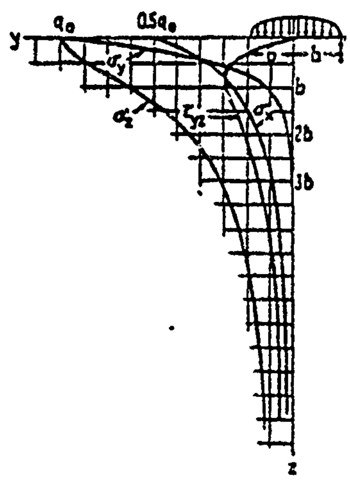


Fig. 2-1 Subsurface Stress Distribution in a Hertzian Line Contact

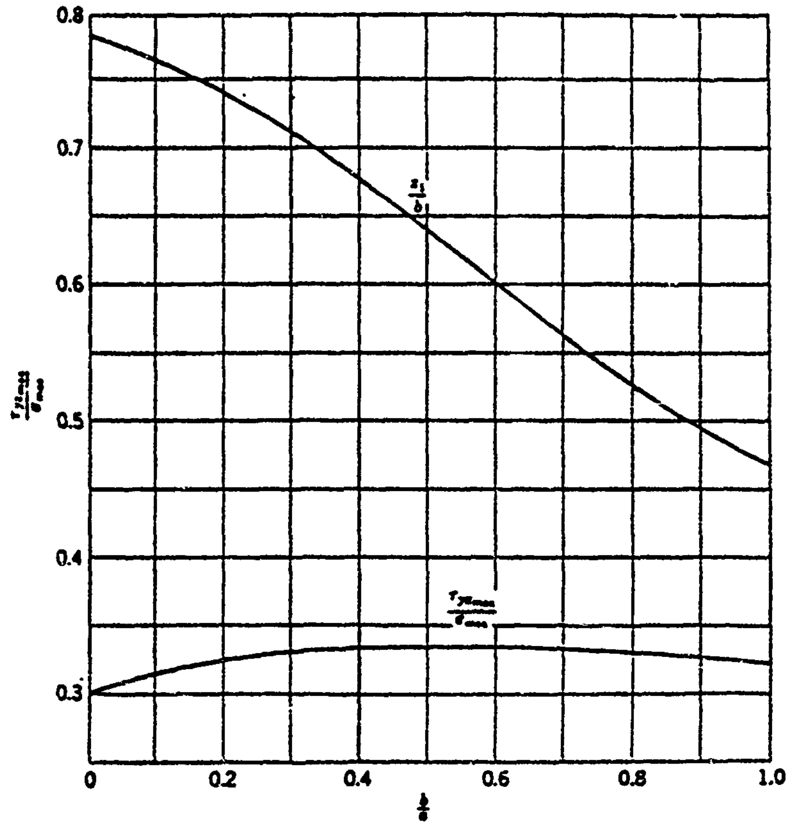


Fig. 2-2 Maximum Subsurface Shear Stress and its Depth Below the Surface in a Hertzian Line Contact

where

τ_o = maximum shear stress

Z = depth at which maximum shear stress occurs

N = number of stress cycles to failure

V = volume of material being stressed

L = length of path

c,e,h = empirical constants

Alternatively, the fatigue life N (number of cycles to failure) for any given probability of survival may be written as

$$N \sim \left[\frac{\ln \frac{1}{S}}{aL\tau_o^c Z^{(1-h)}}\right]^{-e}$$

or

$$N \sim \frac{1}{Z^{(1-h)/e}}$$

when all other parameters are held constant.

The value of h has been suggested as 7/3, and e has been proposed to be 10/9 for ball bearings and 9/8 for roller bearings. Thus,

$N \sim Z^{36/30}$ for ball bearings

$N \sim Z^{32/27}$ for roller bearings.

Both of the above expressions are almost identical, and it can be said that

$$N \sim Z^{1.2}$$

for both ball and roller bearings, assuming, of course, that all other parameters are held constant.

As a further simplification, it may be assumed that the fatigue life is directly proportional to the depth Z where the maximum shear stress

occurs. This assumption may be quite reasonable since the fatigue process itself has a statistical variation and the life cannot be defined in any deterministic fashion.

One assumption in classical rolling bearing fatigue theory is that the material volume stressed lies between the surface and the point of maximum shear stress at depth Z_1. Thus, if a bearing has a life L_1 with the maximum shear at depth Z_1, it may be argued that, before the bearing fails catastrophically, if a layer of material of thickness Z_1 can be removed from the races and the size of the rolling element can be adjusted to compensate for the increased clearance, then the refinished bearing will again have a life L_1. In most instances Z_1 is so large that it is not possible to remove the stressed material entirely, and only a fraction of Z_1 may be removed. The increase in fatigue life in this case may be weighted with a fraction of Z_1 removed. Thus, if half of the stressed layer is removed, a 50% increase in the remaining bearing fatigue life may be expected.

For a typical ball and roller bearing, when the rolling element diameter is increased to compensate for the material removed from the races, the contact stresses can be maintained reasonably constant.

The slight increase in fatigue life, which usually results from the increase in rolling element size, is due to changes in a small number of geometrical parameters. Basically, the half-width increases slightly and the stress drops slightly, both of which lead to a higher fatigue life which has a tendency to counteract the reduction in the fatigue life (as compared to a new bearing) achieved when only part of the stressed volume is removed. As will be shown later, the reduction in fatigue life is usually trivial, since over 90% of aircraft bearing failures is due to factors other than fatigue.

2.4.2 Practical Aspects

Most theoretical fatigue life calculations are based upon AISI-52100 steel, which has been the predominant material for rolling element bearings for over 50 years. To determine the fatigue life of a bearing, the basic dynamic capacity of the bearing must be employed. The dynamic capacity for rolling element bearings has been defined by AFBMA in 1949 and is primarily based on air-melted 52100 steel, hardened to at least 58 R_c. Since 1949, better control of air-melting processes and the introduction of vacuum-melting processes have resulted in more homogeneous steel with fewer impurities. These new steels have demonstrated that they are capable of providing bearing fatigue lives of several times those calculated utilizing the AFBMA method. Life improvements of three to eight times are not uncommon [10]. Other steel compositions, such as AISI M50, because of their improved high-temperature capabilities and resistance to corrosion, have shown even greater improvements in fatigue life. As a consequence, fatigue failures have greatly diminished.

According to Bull [11], about 10% of the bearings that are removed during overhaul appear to have failed from fatigue and are thus not reusable. Another 40% are refurbished. Other scrapped bearings (about 50%) have surface damage of the raceways or the dimensions are not within print. Most of these bearings are restorable.

Cunningham and Morgan [12] report that pitting corrosion has been the most frequent cause for bearing rejection at overhaul. This is closely followed by rejections due to slight brinelling or contamination-induced pitting (for example non-separable bearings which feel rough or tend to hang up during rotation are also rejected under this classification), and by dimensional discrepancies. Table 2-2 presents the bearing rejection by cause as a function of percentage of the total rejects for the years 1969, 1971 and 1977. As indicated, not much change has taken place in the pattern of rejects over the eight-year period. Table 2-3 breaks down the percent of rejects by its source of application; the transmission and engine are shown to be responsible for the highest rates of bearing rejects.

TABLE 2-2

BEARING REJECT BY CAUSE*

	PERCENT TOTAL		
CATEGORY	1969	1971	1977
Specific Directives	28	15	18
Dimensional Discrepancy	15	10	18
Corrosion/Pitting	32	30	29
Handling	7	5	6
Internal Wear	—	15	8
Surface Failure	2	3	1
Cage Wear	2	3	--
Indentation/Contamination	14	19	20

*from Reference [12]

TABLE 2-3

BEARING REJECTS BY APPLICATION*

	PERCENT TOTAL		
MACHINE	1969	1971	1977
Transmission	13	3	35
Accessory	13	4	18
Wheel	2	5	12
Dynamic	16	10	--
Engine	58	41	35

*from Reference [12]

In classifying the failures by cause for the different applications, Reference [12] indicates that the largest number of engine bearing rejects is due to dimensional discrepancies. This is followed by pitting corrosion. In transmissions, pitting corrosion appears to be the primary cause, followed by indentations/contamination. Accessory bearings, on the other hand, are mainly rejected because of specific directives which do not allow reuse of the bearings (internal wear, and pitting corrosion). In general, bearing fatigue which would result in the generation of deep spalls and other serious operation-induced flaws is very rare; according to all sources reviewed, about 10% of all bearing failures would fall into this category. Conversely, close to 90% of all bearings removed during the overhaul process are candidates for rework providing that the rework process can be economically and technically justified.

2.4.3 Operations and Procedures for Bearing Restoration

Because of the theoretical and practical limitations involved in the bearing rework, strict procedures must be proposed and adhered to if a high degree of reliability and product quality is to be maintained.

The process of bearing restoration involves a number of operations which require strict procedures for guidance. These operations are discussed in the following paragraphs.

A. Thorough Cleaning, Possible Replacement of Rolling Elements

This practice is the least expensive of the several options. It requires only cleaning and inspection equipment, plus a selection of new rolling elements. For relatively inexpensive bearings, this may be the only practical approach; the cost of any rework may be greater than the cost of a new bearing.

B. Rehone Races, Replace Rolling Elements

This operation will repair bearings having very shallow surface distress. Since there is some stock removal, totaling up to 0.0010 inch on a raceway diameter, a

stock of slightly oversize rolling elements is required. An additional source of cost for some bearings is disassembly of unseparable bearings by destruction of cages and replacement of those cages.

This operation requires honing equipment, a large selection of new rolling elements, new cages, cage riveting or lug bending equipment, and cleaning and inspection equipment.

C. Rehone Outer Race, Replace All Other Components

This is a viable operation for those bearings for which the major cost element is the outer ring. It is not a practical method for any facility except a bearing manufacturer, but it has a number of advantages where applicable over other restorative procedures:

- Preliminary inspection is minimized because most components will be discarded

- Quoting a fixed price for bearing restoration is possible in advance of preliminary bearing inspection because variables have been minimized

- The bearing restorer can match grind new inner races to the rehoned outer races and thus use standard size rolling elements.

D. Regrind Races to Required (Variable) Depth

This operation has the potential for restoring any raceway which has not overheated. However, there are practical limitations:

- The radial change in raceway dimensions must be equalled within a very few ten thousandths of an inch by an increase in rolling element size, requiring a very large stock of special rolling elements. Each rolling element in an individual bearing must

be identical within from 0.000010 inch, depending on the bearing.

- In ball bearings, it may be necessary to regrind a larger raceway curvature, changing end play and contact angle as well as diametral clearance so a restored bearing may vary from original specifications.
- In roller bearings, the width of the raceway must be considered along with the depth of stock removal in obtaining new rollers.

The equipment required must include race grinding machines and a nital etch facility (to check for grinding burns).

E. Regrind Races to a Specified Depth

This varies from Paragraph D in that raceway grinding is done to a specified depth, whether or not such depth is required for cleanup. If the specified depth is insufficient to remove defects, the bearing is rejected.

This operation simplifies grinding in that in-process inspection is minimized; the operator does not need to check the part repeatedly to be assured that all surface defects have been removed. It also simplifies the roller element stocking problem in that a single oversize dimension (with normal variations) may be ordered to cover all restored bearings of a particular specification.

A variation of this procedure (specified depths of stock, differing for inner and outer raceways, are removed) may prove practical for some sizes of bearings. Facilities for (E) are the same as required for (D).

F. Regrind All Restorable Races, Then Cross-Match

This operation attempts to salvage restorable components from rejected bearings and to restore all practicably restorable raceways while limiting the stock of special rolling elements. Because new bearings of a single

specification vary somewhat from the nominal value in pitch diameter, it is possible to remove stock from an outer race, for example, and to find that it matches, as is, with an existing inner race.

In this operation, races would be treated as individuals: honed or ground, measured, and stored. Rings of a particular raceway diameter would then be selected to match mating rings and existing rolling elements. Implicit in this procedure is the fact that some outer raceways will be too large and some inner raceways will be too small (in diameter) to ever be matched.

A major advantage is the fact that restorable parts which would otherwise be thrown away (e.g., a slightly damaged outer ring from a bearing with a spalled inner race) may be reused.

A problem may exist on limited-life components in that races of the same bearing may have run for different periods of time.

G. Bearing Mounting Surfaces

Bearings whose bores or O.D.'s are out of tolerance or which exhibit severe fretting may frequently be restored by plating. Unfortunately, this is not a simple procedure: first it requires grinding the affected part to obtain a clean surface, then completing a magnetic particle inspection, followed by plating with chromium or nickel to the appropriate specification, and regrinding to size. For most bearings, this is not economically viable, particularly if raceway rework is also required.

Occasionally, the O.D. of an outer ring will grow out of tolerance. Such a ring can be corrected readily by grinding, but hardness must be checked as growth is one symptom of overheating.

If a ring turns on its shaft or in its housing, the motion of its face against a step or flange may damage the face. Normally, this may be corrected by simply face-grinding the surface because tolerances on bearing width are generally much looser than on other parameters. An exception exists in duplex, triplex, or other multiple bearing sets where precise control of bearing face relationsips (within 0.0001 or 0.0002 inch) are required.

- Multiple Bearing Sets

  When two or more ball bearings share an axial load or when two angular contact bearings are preloaded against each other to provide precise axial control, ring face locations must be held to very close tolerances. Whenever a ball bearing is subjected to internal rework or rolling element replacement, end play can be expected to change, and, with it, the relative position of its inner and outer race under load. This relationship must be checked on a duplex gage, and corrections can be made by precise grinding of the face of either inner or outer ring.

H. Inner and Outer Ring Lands

Occasionally, the cage guiding surface of a bearing ring will be roughened or otherwise damaged during bearing operation. Normally, a polishing or honing operation will be sufficient. Tolerances on cage-to-land clearance are usually wide enough to forgive the small amount of stock removal. Almost certainly a new cage will be required if the ring land has been damaged.

It is seldom practicable to replate a damaged land.

I. Cages

In general, used cages may not be reworked beyond removal of silver plate (if present) and replating. It is sometimes possible to remove rivets from two-piece cages, then

reassemble the cage into a bearing using new rivets; this requires great operator care during the disassembly procedure. Roller bearing cages which retain rollers by bent lugs should not be reused after lugs have been straightened for roller removal.

If some bearing wear or distress is indicated during preliminary inspection, cages should be subjected to fluorescent penetrant inspection for cracks; silver-plated cages must be stripped to base metal before the inspection can be performed.

Cages showing roughened metal on the land-riding surface should be discarded. A polishing of land-riding surfaces and pocket surfaces is to be expected. Any pounding out of these surfaces is cause for rejection.

Cages requiring silver plate must be replated before being reinstalled in bearings. Some bearing specifications have a cage balance requirement; balancing may be accomplished by selective removal of stock from the face of the cage. Checking for balance requires specialized equipment.

J. Rolling Elements

If simple cleaning procedures are inadequate to permit the return of a bearing to service, rolling elements should be discarded. Costs of a thorough inspection of a used roller or ball are greater than the price of a new element.

In addition to general procedures guiding the bearing refurbishment processes, such as restoration and rework, specific addenda covering each part number may be required. This will aid in the process of maintaining the refurbished bearing at the specification level designated by the original engine manufacturer.

2.5 Inspection and Selection of Bearings for Refurbishment

Classification of used bearings for rework and eventual reuse requires bearings to be subjected to 100% inspection. The inspection procedure can be divided into two groups: diagnostic and dimensional.

2.5.1 Diagnostic Inspection Requirements

The diagnostic inspection group is more difficult to execute since current inspection procedures call for either visual examination or inspection by touch. Because the results of diagnostic inspections are dependent on the senses of the inspector, a high degree of confidence in repeatability cannot be assured, particularly when numerous individuals are involved in interpreting procedures. A typical example of visual inspection criteria is given in Table 2-4. In most cases, the use of a spherical-tipped probe is recommended for determining whether a crack, pit, or spall is deep enough to cause the bearing to be rejected. To make such a determination, the inspector moves the probe over the surface. If movement of the probe is felt over a pit, the specific part is not acceptable. Because different pit sizes are permitted for different types of bearings, a relationship has been established between the pit size and the radius of the probe's sphere. This relationship is also described in Table 2-4. A 10X eye loop is often used to visually inspect the affected areas and to determine the extent of damage. Normally, any dents, corrosion, pitting, fretting, and other fine surface imperfections are cause for bearing rejection.

Bearings that are disassemblable (such as split inner race bearings and most of the cylindrical roller bearings) can easily be subjected to visual inspection. In numerous cases, the normal diagnostic visual inspection cannot be performed until the bearing is fully disassembled; a majority of bearings employed in an aircraft system are not easily disassembled without the destruction of at least the bearing cage. This means that a significant number of bearings which could normally be reused would be automatically rejected. In some cases, bearings that cannot be disassembled are subject to a quick test whereby the operator or inspector turns the bearings in his hands, trying to feel for large pits or spalls, or mounts the bearing on a spindle and determines by feel whether the bearing runs rough or smooth. The U.S. Navy and other parts of the defense establishment have used a vibration sensing machine known as the Anderometer for this purpose. The Anderometer determines the noise levels emanating from the radial movement between the races and converts these into anderons. The measurement takes place over a frequency spectrum that is divided into three parts: low,

TABLE 2-4

VISUAL INSPECTION CRITERIA FOR POWER PLANT BEARINGS*

Condition or Damage	Functional Surfaces: Balls	Functional Surfaces: Rollers	Functional Surfaces: Raceways	Non Functional Surfaces
Brinelling				
a. False	Acceptable if no depth, otherwise see following			NA
b. True				
Ball/Roller Sizes	Max Length Width	Max Length Width	Max Length Width	NA
(1) 0.5 in. dia. or less use 0.040 in. radius scriber	0.015 in. 0.010 in.	Same	Same	
(2) 0.5 to 1 in. dia. use 0.080 in. radius scriber	0.025 in. 0.010 in.	Same	Same	
NOTE: Brinelling sufficient to cause roughness when the bearing is rotated shall be cause for rejection.				
c. Installation or Removal	Not Acceptable	Same	Same	NA
Crack	Not Acceptable	Same	Same	Same
Indentations Grouped by ball/roller dia.	Max Dimension			(1) Bore and OD Surfaces
(1) 0.5 in. dia. or less use 0.040 in. radius scriber	0.015 in.	Same	Same	150mm bore—0.125 in. max size Over 150 mm bore—0.250 in.
(2) 0.5 in. to 1 in. dia. use 0.060 in. radius scriber	0.025 in.	Same	Same	(2) Split Inner Ring Surfaces Acceptable if no high metal extends to raceway.
Pitting	Max of 3 pits in ¼-in. circle	Same	Same	NA
(1) Corrosion Ball/Roller Sizes	Max Pit Size	Max Pit Size	Same	Any amount if diameters of pits do not exceed 0.030 in and affect less than ¼-in. area.
(a) 0.5 in. dia. or less	0.010 (0.030 in. scriber)	0.015 (0.040 in. scriber)	Same	
(b) 0.5 in. to 1 in. dia.	0.015 (0.040 in. scriber)	0.020 (0.050 in. scriber)	Same	Three 0.050 in. dia. pits in any ¼-in. dia. area. Depth not to exceed 0.010 in.
(2) Electrical Arcing Scratches	Not Acceptable	Same	Same	Same
Ball/roller sizes	Max size	Circum | Axial		Acceptable
(1) 0.5 in. dia. or less	0.010 (0.030 in. scriber)	0.010 3 | None if felt with 0.030 in. scriber	Same	
(2) 0.5 in. to 1 in. dia.	0.015 (0.040 in. scriber)	0.015 3 | 0.040 in.	Same	
Skidding	Not Acceptable	Same	Same	NA
Smearing	Not Acceptable	Same	Same	NA
Spalling	Not Acceptable	Same	Same	NA
Wear General	Must meet dimensional & radial play limits	Same	Same	Same
Roller Ends				
(1) Superficial scratches	NA	Acceptable	NA	NA
(2) Wear	NA	.0005 in. max	NA	NA
(3) Eccentric wear or burnishing	NA	Not Acceptable	NA	NA

*From Reference [12].

medium and high. Although the Anderometer has been employed for 20 years, its capability to reliably separate good bearings from bad is still unproved. The Anderometer is reliably capable of diagnosing quiet and noisy bearings, and the classification noisy does not necessarily imply that a bearing is not reusable.

The difficulties encountered in the process of diagnostic bearing inspection are highlighted in Reference [15]. To quote from this specification:

"Bearing processing involves special skills and training requirements. Some of the skills are as follows:

- Detect defective bearings by visual and microscopic examination.
- Evaluate bearing condition with respect to specialized application requirements.
- Make judgment decisions as to bearing acceptability based on engineering requirements.
- Dimensionally inspect bearings using ultra-precision gaging equipment measuring in millionths of an inch.
- Test bearings for vibration and smoothness characteristics, and determine acceptability for specific applications.
- Perform first article inspection on new bearings for conformance to drawing requirements.

"Personnel performing bearing processing should satisfy the following physical requirements:

(1) VISION TESTS - Vision tests shall be performed by an oculist, optometrist or other professionally recognized personnel. Personnel shall be required to pass vision tests at original qualification, and each calendar year thereafter.

Vision requirements - The following minimum vision requirements shall apply:

a. Distant vision shall equal 20/30 in at least one eye, either uncorrected or corrected.

b. Near vision shall be equal to normal vision, as prescribed by the optical profession, in both eyes, either corrected or uncorrected.

(2) DEXTERITY TESTS - Dexterity tests shall be required for personnel to be assigned to instrument bearing processing. Instrument size bearings include those under 1 inch

outer diameter. Personnel to be assigned responsibilities with precision gaging equipment shall be given dexterity tests.

(3) ACIDITY TESTS - Personnel to be assigned to bearing processing shall be tested by the medical department for high acidity levels in perspiration residues. Personnel with a high acidity level will cause severe corrosion damage to bearings and precision gaging equipment.

(4) GENERAL TESTS - Personnel to be assigned to the clean room area shall be tested for compatibility with such confining and highly restrictive work functions. The following undesirable characteristics shall be considered when selecting clean room personnel:

a. Excessive nervousness

b. Chain smoker

c. Severe dermatologic problems

d. Severe allergy problem with excessive sneezing

"Finally, the following technical requirements and qualification/operational tests should be satisfied:

(1) TECHNICAL REQUIREMENTS

a. Personnel must know general theory concerning operation of rolling and plain bearings.

b. Personnel must know general theory concerning gaging, operation, practices, and techniques.

c. Personnel must be thoroughly familiar with processing and inspection requirements contained in ref. (13).

d. Personnel must be able to interpret inspection and test indications upon which to base acceptance or rejection of bearings in accordance with this ref. (2), manufacturers drawings, and contractor requirements.

(2) QUALIFICATION EXAMINATIONS - Personnel assigned to the inspection and acceptance areas of the bearing processing facility shall be qualified by examinations. Examinations can be written, or oral, and operational. Examination will include sample bearings with known defects and/or deficiencies, that shall be detected and identified by the person being examined. The qualification status of a bearing inspector shall be maintained by a continuous record of satisfactory workmanship. When personnel have been away from this kind of work for more than 1 year they will be requalified in accordance with requirements contained below.

"Qualification tests - Applicants shall take written or oral tests to cover the following topics:

a. Basic theory of bearings and lubricants including nomenclature.

b. Methods of checking bearing dimensions.

c. Common types of defects and deficiencies causing rejection.

d. Acceptable marks, dimensional variations, and wear limits.

e. Cleaning, lubrication, preserving, packaging, and identification procedures.

Operational tests - Operational tests shall include sample bearings with acceptable borderline and unacceptable conditions- - -."

These requirements are extremely difficult to follow because most of them are subject to interpretation. Consequently, it is not surprising to find in diagnostic inspection the acceptance criteria to be at variance from one overhaul depot to another in spite of the fact that Reference [15] is almost universally used.

2.5.2 Dimensional Inspection

Dimensional inspections are based upon gaging or measurement of the physical dimensions of a part. Considering the tolerances involved in bearings, this process is comparative in nature and involves the comparison between the measured dimension to a standard gage.

Fully assembled bearings are normally subjected to one or more of the following measurements: the radial internal clearance under a specified gaging load, friction torque, starting torque, bore size, outer diameter size, bearing width, and internal axial play.

CCAD appears to be reasonably well-equipped to perform dimensional inspection. The facilities and equipment currently on record (see Appendix B) should enable CCAD to meet most, if not all, new requirements.

2.5.3 Identification and Coding of Bearings

The recommended methods to be employed in identifying bearings for DOD use

are described in this section. A brief explanation is also given of the Process Coding to be utilized. A cursory examination of the CCAD methods indicates that these are generally in line with the DOD recommendations.

2.5.3.1 Bearing Identification - National Stock Numbers (NSN). All Federal Stock Numbers are currently being converted to National Stock Numbers (NSN). The NSN has been established to identify products produced by the United States, and its allies. An additional two digits have been added to the basic stock number between the four-digit stock class and the seven-digit item identification number. United States has been assigned the -00- and -01- codes. Examples of NSN's that identify bearings produced by the United States are 3110-00-799-0376 and 3110-01-540-4662. Rolling element bearings, except for a few specialized cases, are assigned a Federal Stock Code (FSC) of 3110. See Figure 2-3 for an example of an NSN.

Prime Contractor Part Numbers (P/N). Part numbers assigned to a bearing by the manufacturer of an aircraft, engine, or component, are often referred to as prime contractor part numbers. These numbers always refer to a specific drawing for a particular bearing. The drawing calls out all the special features and design criteria that fully describe the bearing. Special quality control and/or selective screening requirements that may exceed normal bearing manufacturer's requirements are usually specified. For this reason the bearing manufacturer's part number, even though it is a complete number, cannot be used alone to substitute and/or procure these bearings.

Bearing Manufacturer's Part Numbers (Vendor Number). The part number assigned by the manufacturer to a particular bearing describes that bearing as to size, type, precision, lubricant, retainer type, internal clearances, and other special characteristics and/or construction features. It should be noted that the part number marked on the bearing is only the basic portion of the complete part number that fully describes the bearing.

The basic bearing part number cannot be used to substitute or procure rolling bearings for most aircraft applications.

```
       (NCB) National Codification Bureau Code
   3110-00-293-8567-FN
        FSC       NIIN  SMIC
Federal Supply  National Item          Special Material
Classification  Identification Number  Identification Code
```

Fig. 2-3 Example of National Stock Number

2.5.3.2 Bearing Application Grouping. Rolling bearings are categorized into five major groups [15] as follows:

- Group A - Powerplant Bearings' including gas turbine and reciprocating engine bearings, gearbox bearings, and related accessory bearings.
- Group B - Airframe and General Bearings; including rod ends, plain bearings, wheel bearings, and aircraft control bearings.
- Group C - Instrument Bearings; including all bearings used in aircraft instruments and related equipment.
- Group D - Rotating Electrical Bearings; including generator, starter, small motor, inverter, and hydraulic accessory bearings.
- Group E - Helicopter Bearings; including gearbox, rotor, and drive shaft bearings.

2.5.3.3 Bearing Coding - Process Code. An identification mark placed on all used bearings differentiates between new and processed used bearings. The code mark indicates the bearing has been previously used, inspected, and certified by an authorized government facility, and that it is acceptable for reinstallation in an aeronautical component, installation, and/or airframe. Where bearing size and structural design permit, the code designation indicating the processing activity is placed on the ring face after the manufacturer's part number. The vibratool or the chemical etch are approved methods for marking bearings. The following code designations is used by depot level activities:

a.	NAVAIREWORKFAC	Alameda----------------A
b.	NAVAIREWORKFAC	Jacksonville----------J
c.	NAVAIREWORKFAC	Cherry Point----------M
d.	NAVAIREWORKFAC	Norfolk----------------N
e.	NAVAIREWORKFAC	Pensacola--------------P
f.	NAVAIREWORKFAC	North Island----------S
g.	CCAD	Corpus Christi--------C

Smaller bearings, except miniature bearings, are marked with a single point following the manufacturer's part number.

Bearings that have operated for a service tour, that were previously processed and code marked by a facility, and are acceptable for additional use are marked as follows:

- A number one after the initial processing facility code.

  Example: C 1

- Additional numerals for each additional service tour after the initial processing facility code

  Example: C III (4 service tours)

Rework Code - Bearings that have had any of the special rework/refurbishing operations are identified with the code of the rework activity and the letter R after the manufacturer's part number.

Time Code - Certain bearings receive a special mark to indicate the total operating time that has elapsed since the bearing was new. Each time the bearing is removed from the assembly after a period of service, the time that has accumulated since the last inspection is added to the previously recorded time. The accumulated operating time data is used to monitor life-limited bearings, establish realistic life limits and realistic time between overhauls (TBO), and to provide useful data to isolate specific applications that need design changes for improved life.

2.6 Summary of Current Status in Bearing Restoration Technology

Bearing restoration as such has been common in the Commercial Airlines Industry for the past 20 years. The restoration primarily consists of honing raceways, replacing rolling elements and restoring or replacing cages. Bearings with more severe flaws, such as pits and spalls, are currently being discarded. The bearing restoration process at the Corpus Christi Army Depot's Bearing Shop is, in many ways, similar to that currently practiced by the commercial airlines with the exception that stripping and silverplating of cages and replacement of cages and full components of rolling elements is limited to a few bearing types only.

Theoretical considerations as well as practical tests performed in the past by NASA indicate that close to 90% of all the bearings reaching a Bearing Shop such as CCAD's could be saved by the expansion of the bearing restoration operations to cover more extensive rework such as grinding and matching of the reground bearings with new rolling elements of larger size.

The implementation of an expanded rework program will require the addition of new machinery and new diagnostic equipment. As has been demonstrated in this section, current inspection procedures, particularly those related to the functional inspection of the races and rolling elements as specified by Reference [1], are difficult to implement and standardize because of the heavy dependence upon the individual traits and characteristics of the inspectors. It is indeed difficult to overemphasize the fact that, in order to raise the overall quality level of new as well as refurbished bearings, more reliable diagnostic techniques will have to be applied. These techniques should be based upon new equipment developed within the past decade which utilizes the state of the art in the field of electronics and microprocessing.

3.0 STATISTICS ON CURRENT CCAD BEARING REFURBISHMENT ACTIVITIES REVIEW

This section presents statistics on the current amounts and replacement values of bearings handled by the Bearing Shop for the period 1974 through 1980. The analysis and presentation provides a statistical Bearing Shop history and the scope of resources available for future activities, including expanded rework.

3.1 Data Sources

Most data used in this section were obtained from two sources:

- Bearing Shop historical records (hand-written entries) on flow of bearings through the Shop over the period
- A current-inventory computer listing from the ASTORS containing used bearings from the Bearing Shop that are stored for possible future rework. This listing is as of October 1980.

Other sources are documented separately.

The ASTORS printout is an overview of the ASTORS bearing inventory as of the start of fiscal year (FY) 1981. The used bearings in ASTORS provide a major source for bearings that would be reworked in an expanded facility. They represent an accumulation (since the second quarter of FY 1979) of bearing candidates for rework sent to ASTORS by the Bearing Shop.

The Bearing Shop flow data describe the bearings that passed through the Bearing Shop from the start of the calendar year (CY) 1974 through FY 1980. This discussion focuses on the data for FY 1979 and FY 1980 because:

- The level of detail presented increased during the 1974-1980 period, with FY 1979 and FY 1980 having the same level of more detailed information.
- The latter years are more likely to represent the mix of bearings that might enter the Shop in the future than are the earlier years of the entire period.

Figure 3-1 shows the major elements of this flow and gives the FY 1980 data as examples.

Two major types of bearings are handled by the Bearing Shop: new replacement bearings from manufacturers and used bearings from system maintenance operations at CCAD and other installations The analysis presents data separately on both types.

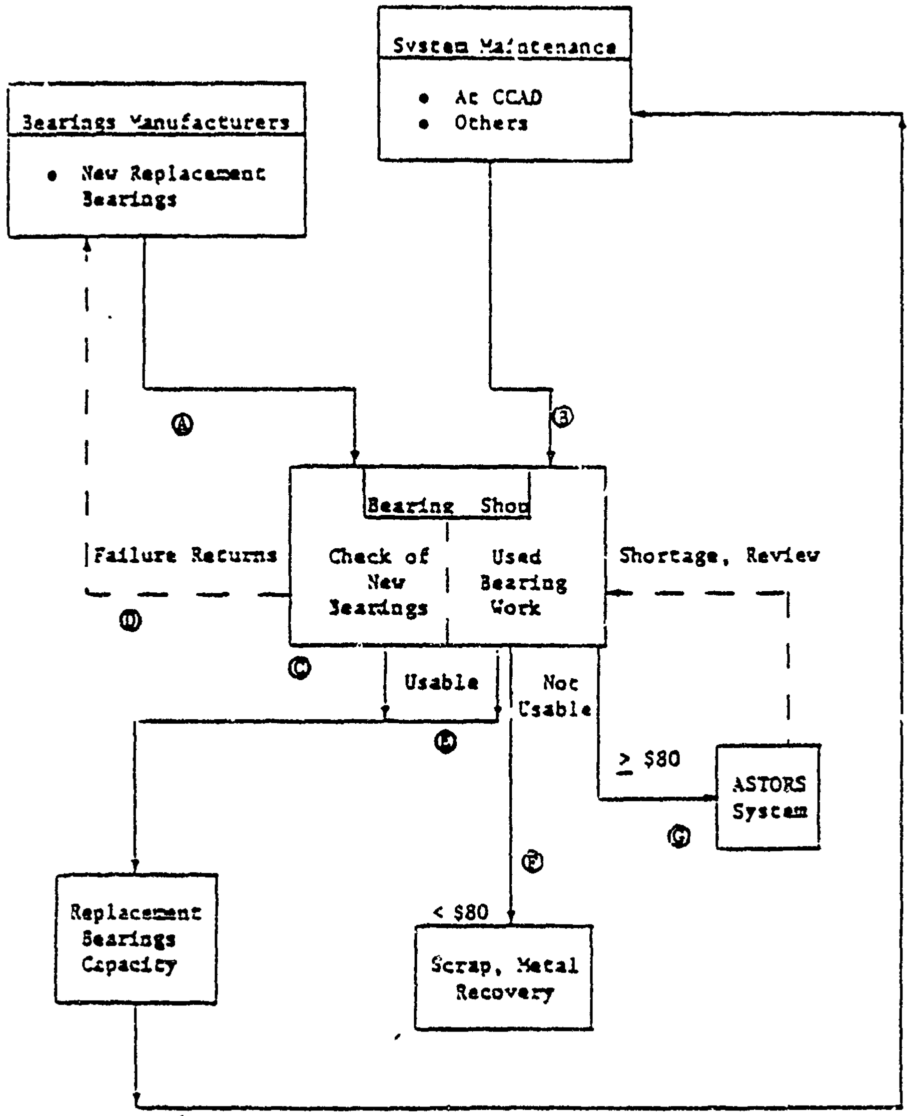
3.2 The Total Used Bearing Flow

Over 193,000 bearings flowed annually through the Bearing Shop between 1974 and 1980. This annual flow fluctuated over the period, with the lowest flow (148,200 bearings in 1976) being 23% below the mean, and the highest flow (214,314 in CY 1977, including the transition quarter) being 11% above the mean. Table 3-1 shows both these data and others discussed in the following paragraphs.

A large number of different bearing designs are involved; for example, in FY 1980, 357 different Part Numbers are listed in the Bearing Shop records. These include integral components of engines, transmissions, rotor heads and controls, airframes, instruments, and other Army helicopter systems. In addition, the Bearing Shop has processed bearings from other vehicles (e.g., trucks) on a very limited basis.

The value of these bearings can be stated in terms of their replacement costs (the cost that would be incurred by the Army for the purchase of new replacement bearings). This report uses the unit costs provided by the Bearing Shop as of October 1980. These costs fluctuate widely. (For example, a number of bearings cost less than $1.00 each; and one bearing, Part Number 114D5161-1 in the CH-47, costs $2,034.00.) Bearings priced above $80 will be focused on two reasons:

- The $80 and above price was previously established (See Appendix A) as an economically acceptable limit for rework



KEY TO LETTERED CODES

Code	Meaning	Total for Code	Percent of Total
	Bearings Inducted		
A	New Replacement Bearings	57,283	28.6%
B	Used Bearings	143,046	71.4%
	TOTAL	200,329	100.0%
	Bearings Sent Out		
C	New Replacement Bearings Passed	56,983	28.4%
D	New Bearings Rejected	300	0.1%
E	Used Bearings Passed	98,093	49.0%
F	Used Bearings Rejected to Scrap	28,436	14.2%
	Used Bearings Rejected to ASTORS	16,517	8.3%
	TOTAL	200,329	100.0%

Fig. 3-1 CCAD Bearing Flow (Current System, FY 1980 Example)

TABLE 3-1

SUMMARY OF ANNUAL BEARINGS FLOW

Fiscal Year	Bearings Inducted			Bearings Passed			Bearings Rejected			
	Total	Used	New	Total	Used	New	Total	To ASTORS	To Scrap	New
1974	208,960	-[1]	-	164,416	-	-	44,544	-	-	-
1975	198,215	-	-	153,053	-	-	45,162	-	-	-
1976	148,200	-	-	112,171	-	-	36,029	-	-	-
1977[2]	214,314	-	-	162,184	-	-	52,130	-	-	-
1978	205,792	-	-	158,310	-	-	47,482	-	-	-
1979	176,824	124,912	51,912	138,791	87,057	51,734	38,033	20,193	17,662	178
1980	200,329	143,046	57,283	155,076	98,093	56,983	45,253	16,517	28,438	300
Average Totals 1974-1980	193,233	-	-	149,143	-	-	44,090	-	-	-
Average Totals 1979-1980	188,577	133,979	54,598	146,934	92,575	54,359	41,643	18,355	23,049	239

[1]Data Not Available For All Dash Entries
[2]Includes transition quarter, 6-9/1976.

- There is a substantial supply of bearings at this unit price in the ASTORS. This supply represents an excellent source for savings through rework.

The unit cost issue also has other important aspects. An analysis to select candidate bearings for rework has resulted in several iterations of short lists for such bearings. The first such evaluation listed all bearings with unit costs of $80 or above in the FY 1980 Shop flow and in ASTORS. Of these, the percentage of bearings inducted that could be reasonably recovered by reconditioning work was analyzed. This information was balanced against the number actually being recovered by the current Bearing Shop activities to arrive at a first grouping of bearings that might be available for recovery under rework. For each such part number analyzed, estimated lot sizes were drawn up of these bearings available from the annual Shop flow. A similar analysis was performed with the ASTORS data. Then, for each part number, the lot size was multiplied by the unit price to obtain an estimate of the replacement value of the lot.

As will be demonstrated in Section 4.0, a small amount of part numbers can account for a very large percentage of the total bearing resource for rework, on both a lot-size and a replacement-value basis. This fact is very important to the selection of a rework approach, and to its justification.

Finally, the unit cost incurred may be strongly affected by the lot size of the bearings ordered. A hypothetical example of this has been supplied by TRW. A typical order is in the range of 100 bearings. Table 3-2 shows that, as the lot size ordered decreases, the unit cost increases significantly. The example presented is for a bearing with a unit cost of $200 at a lot order of 100. The price increases to $220 for lots of 50-99, to $240 for lots of 25-49, and to $260 for lots of 11-24. For lots between 1 and 10, the unit price is:

$$\text{Price} = \$260 + \frac{100}{n}$$

where

n = the lot size.

TABLE 3-2

EXAMPLE LOT SIZE EFFECT ON UNIT BEARING PRICE

Lot Size	Unit Price ($/bearing)
100	$200
50-99	$220
25-49	$240
11-24	$260
10	$270
9	$271
8	$273
7	$274
6	$277
5	$280
4	$285
3	$293
2	$310
1	$360

Source: TRW Bearings Division

The smallest order (one bearing) has a unit cost of $360, or 80% higher than the unit cost at the 100 lot size.

The unit cost data from the Bearing Shop exhibit fluctuations between fiscal years for the same Part Number of greater percentages than the inflation rate. Changes in lot size and other affects (rush orders, change of manufacturers, change of bearings, etc.) could account for a large percentage of the fluctuations. The analysis of these causes versus unit price was not conducted in this study due to time and information constraints. However, fluctuations may play a key role in the cost of procuring new replacement bearings. Since the justification for a rework facility depends on the savings obtained by not procure new replacement bearings due to higher availability of reworked used bearings, the optimization of lot size orders may affect the level of justification. Two related key points should be kept in mind. First, some fluctuation in lot size is a normal part of replacement parts procurement. Surges up and down in demand and supply will occur. Second, the implementation of a rework facility offers the opportunity to address many issues of new replacement bearings procurement that may exist. Such a facility provides for increased availability of replacement bearings and, theoretically, allows for a more even procurement of new replacement bearings.

3.3 Used Bearings Rejected and Passed

Of the used bearings inducted into the Bearing Shop in FY 1979-80, 92,575 of the 13,979 average annual total (see Table 3-1), or 69%, were passed. (The Bearing Shop uses the terminology "sold" for bearings qualified as reusable.) The remaining 31%, 41,643, were rejected. This represents an already high recovery rate for the current Bearing Shop activities. While the current reconditioning activities are not extensive, they appear to be recouting for reuse a high percentage of the used bearings taken out in maintenance.

The remainder, those rejected in the inspection process, represent the gross resource of bearings available for rework.

3.4 Rejected Used Bearings Disposition

Of the 41,643 rejected used bearings, 55%, or 23,049, are scrapped. The general rule governing disposition of the rejected used bearings is that bearings with a unit price of less than $80 are scrapped (a dollar cutoff set by the Bearing Shop). The remaining 45%, or 18,355 bearings enter into the ASTORS system. These are generally the more expensive bearings (a unit price equal to or greater than $80), although ASTORS does also contain a large number of less expensive bearings.

In the following discussion, the aircraft and components housing the specific bearings are identified by code. The section of a group or segment of bearings for rework will come from the list of rejected bearings from the annual Shop flow, and from those in ASTORS. While more systems are included, those from the most frequently overhauled helicopters have been chosen for focus. In addition, the generally higher level of unit cost and the ability of this analysis to develop more complete data have led to a further focus on the engine, transmission, and rotor head and control bearings from these aircraft. Table 3-3 shows the breakout for ASTORS of bearings from these systems. These bearings represent approximately 58% of all the bearings in ASTORS (the remainder are classified as "other" at this time).

One major area of concern is that current data are insufficient regarding the condition of the reject used bearings with respect to the extent of rework that they would require. The current Bearing Shop inspection activity codes the rejected bearings by the estimated nature of the problem (condition code). Table 3-4 shows the breakout at ASTORS by condition code. A summary for the ASTORS inventory list of 36,710 bearings have a condition code of "UK", or unknown. Moreover, the more specific codes do not allow for a direct estimate of the number of such bearings that would require certain levels of rework. A way of roughly estimating the rework required, taking into account the previously mentioned uncertainties, is presented in Section 5.0.

TABLE 3-3

ASTORS BEARINGS BY SYSTEM

System Code	All Number of Bearings
A/E Engine	3,845
A/T Transmission	4,654
A/R Rotor Head	4,617
B/E Engine	962
B/T Transmission	4,592
B/R Rotor Head	
C/E Engine	1,640
C/T Transmission	1,076
C/R Rotor Head	
D/E Engine	
D/T Transmission	67
D/R Rotor Head	
Other	15,257
	36,710

TABLE 3-4

ASTORS INVENTORY BY CONDITION CODE

Condition Code Description	Condition Code	Number of Bearings With Code
Problem With Race	AA	4,785
" " Race and Rolling Element	AB	9,783
" " Race and Cage	AC	130
" " Rolling Element	BB	3,183
" " Rolling Element and Cage	BC	57
" " Cage	CC	987
" " Race, Rolling Element and Cage	DD	38
" " Finite Aspect	LL	416
Obsolete	OO	369
Out-of-Tolerance	OT	217
Salvage/Scrap	SS	1
Unknown Problem	UK	16,604
		36,570
Miscellaneous Codes Not Identified by Problem		140
TOTAL, All ASTORS		36,710

3.5 New Replacement Bearings

Many of the bearings flowing through the Bearing Shop are new replacement bearings from bearing manufacturers. During FY 1979-1980, for example, 29% of all inducted bearings were new replacement bearings. Almost all of these bearings are qualified for use during the quality control checks; an average of only 0.5% of the new replacement bearings are found to be defective. All defective bearings are returned to the manufacturers. As such, the new replacement bearings do not represent a part of the potential resource for rework.

4.0 SEGMENTATION OF BEARING INVENTORY

This section describes the step-by-step procedure employed in the screening and segmentation of bearing rework candidates. It will be shown that most of the replacement costs can be recovered from the rework of a relatively small and selective grouping of bearing part numbers.

4.1 Current Inventories

The source of bearings for rework is divided into three major groups:

- Used bearings delivered to the Bearing Shop from the helicopter systems maintenance activities at CCAD.
- Used bearings delivered to the Bearing Shop from system maintenance activities at locations other than CCAD.
- The bearings inventoried in the Automated Storage and Retrieval (ASTORS) system.

The used bearings are inducted into and sent through the Bearing Shop; certain percentages of these used bearings are considered not immediately reusable and are rejected. Some rejected bearings (about 12% of all inducted used bearings) are sent to ASTORS. (These tend to be bearings whose unit cost is $80 per bearing or higher.) Approximately 69% of the bearings inducted are passed for reuse, and approximately 19% are scrapped.

These rejected used bearings become candidates for annual rework. Other such candidates come from the ASTORS inventory, drawn down at a selected annual rate.

4.2 Selection of Segments for Rework

Selecting the most critical and economical segments of these available bearings will depend on several factors. The selection of a bearing segment for rework will be based first on the unit replacement cost. Further iterations shall consider both criticality factors and the critical bearings initially left out of the rework segment due to focus on unit cost. The final analysis shall focus on the justification for the entire segment,

regardless of how the individual bearing unit replacement costs compare with the average per-bearing rework cost for the entire segment. The segment may thus contain bearing types of relatively low unit replacement cost (or relatively high rework costs) but of relatively high criticality. The rework facility must be able to offer rework for relatively cheap, but scarce, bearings.

To develop an appreciation for the bearing replacement cost versus quantity relationship in the Bearing Shop flow, a simplified breakdown was performed using only the A/E engine bearings. A summation of the breakdown is given in Table 4-1 where the bearings were divided into three categories: small bearings (bore diameter less than 20 mm), medium-size bearings (bore diameter greater than 20 mm but less than 50 mm), and large bearings (bore diameter greater than 50 mm). Table 4-1 shows that a majority of the bearing population processed through the Shop consists of small, relatively low-cost bearings. Quantatitively, these bearings amount to 65% of the total flow, while the replacement cost is only 5% of the total. Of even greater interest is the fact that, whereas the average reject rate of the entire FY 80 A/E bearing flow is about 31%, the reject rates of the larger bearing are much higher - the medium-size bearings showing a reject rate of close to 50%. These results clearly document that, at least from the economic point of view, focus should be placed on bearings with bore diameters larger than 20 mm. Another important fact was brought to light when the A/E engine bearings were tested for changes in replacement value (actual change in unit cost per bearing). The test sample consisted of the 16,854 used A/E bearings "sold" (passed as acceptable) in FY 80. The replacement value of these bearings, based upon FY 80 unit costs, was $462,687. However, when FY 81 unit costs were substituted, the replacement value more than doubled to $940,333. The importance of this finding is further discussed in Section 6.0.

The next step in the evaluation investigated the segment of used bearings from the Shop flow* that had a unit cost greater than $60 per bearing** in

*Using FY 1980 Shop flow data on used bearings.
**This price was selected in lieu of the $80 cutoff to provide a margin for the future price increase.

TABLE 4-1

A/E BEARING FLOW THROUGH SHOP

(FY 80)

	<20 mm	>20 <50 mm	>50 mm
1. Total Ind.	11,870	4,646	1,758
2. FY 1981 Replacement Value	79,034	590,684	808,170
3. Total Sold		2,370	1,067
4. Total Rejected		2,276	691
5. Percent Rejected (4/1 x 100)		49	39

October 1980. Tables 4-2 through 4-10 show data, by helicopter systems, on the number and economic value of these bearings. These tables further segregate the information by bearing bore diameter into three ranges.

It is evident that the preponderance of bearings in the price range investigated is over 20 mm in bore diameter. Only the C/E engine and C/T transmission have bearings in the range with bore diameters equal to or less than 20 mm. In addition, the Bearing Shop already recovers the majority of these bearings; over 80% of all inducted were sold* in the fiscal year 1980. Finally, the cost of replacement for the rejected bearings becomes significant when looking at overall costs. With reference to Tables 4-2 through 4-10, the total purchase cost (using October 1980 figures) of replacing all bearings with new replacement bearings would be about $10.5 million. This first analysis generally indicates that a relatively large dollar value is assigned to relatively few large bearing types. Economy would thus dictate that the rework facility should concentrate on segments of expensive bearings when other criticality factors are omitted.

The second evaluation investigated critical bearings in terms of application. CCAD engineers have produced a document** which lists bearings requiring 100% inspection by the Bearing Shop. Because only bearings critical from the standpoint of application require such inspection, the analysis of these bearings by part number reduced the lists of rework candidates to final segments of the initial candidates for rework.

The second criticality factor, supply lead time, could not be sufficiently analyzed with available data and time. Consequently, any particular lead-time problems created by specific types of bearings could not be calculated.

Based on the reasoning of the previous paragraphs, the final segments of rework candidates were selected by category. This is detailed in the following paragraphs.

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*Qualified as reusable by the Bearing Shop.
**Document MEEI6940, Appendix C.

TABLE 4-2

A/E ENGINE COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >\$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		4,699	1,758
2. 1980 Dollar Value		\$593,913	\$808,170
3. Total Sold		2,404	1,067
4. Total Rejected		2,295	691
5. Percent Rejected (4/1 X 100)		49%	39%
6. Sold Dollar Value		\$300,220	\$483,775
7. Lost Dollar Value (2-6)		\$293,693	\$324,395

TABLE 4-3

B/E ENGINE COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >\$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		1,636	1,497
2. 1980 Dollar Value		\$199,010	\$665,368
3. Total Sold		941	877
4. Total Rejected		695	620
5. Percent Rejected (4/1 X 100)		42%	59%
6. Sold Dollar Value		\$111,107	\$416,493
7. Lost Dollar Value (2-6)		\$ 87,903	\$248,875

TABLE 4-4

C/E ENGINE COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted	412	3,483	
2. 1980 Dollar Value	$26,834	$332,050	
3. Total Sold	332	2,663	
4. Total Rejected	80	820	
5. Percent Rejected (1/4 X 100)	19%	24%	
6. Sold Dollar Value	$ 21,623	$249,973	
7. Lost Dollar Value (2-6)	$ 5,211	$ 82,077	

TABLE 4-5

A/T TRANSMISSION COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		1,848	3,750
2. 1980 Dollar Value		$341,317	$981,744
3. Total Sold		1,584	2,955
4. Total Rejected		264	795
5. Percent Rejected (4/1 X 100)		14%	21%
6. Sold Dollar Value		$297,171	$794,526
7. Lost Dollar Value (2-6)		$ 44,146	$187,218

TABLE 4-6

B/T TRANSMISSION COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		603	6,782
2. 1980 Dollar Value		$66,370	$4,645,252
3. Total Sold		280	4,589
4. Total Rejected		467	1,293
5. Percent Rejected (4/1 X 100)		77%	19%
6. Sold Dollar Value		$24,750	$4,005,465
7. Lost Dollar Value (2-6)		$41,620	$ 639,787

TABLE 4-7

C/T TRANSMISSION COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted	292	1,217	877
2. 1980 Dollar Value	$36,208	$495,772	$207,044
3. Total Sold	275	897	594
4. Total Rejected	17	255	283
5. Percent Rejected (4/1 X 100)	6%	21%	32%
6. Sold Dollar Value	$34,100	$383,508	$147,324
7. Lost Dollar Value (2-6)	$ 2,108	$112,264	$ 59,720

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TABLE 4-8

D/T TRANSMISSION COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >\$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		246	
2. 1980 Dollar Value		\$44,571	
3. Total Sold		148	
4. Total Rejected		98	
5. Percent Rejected (4/1 X 100)		40%	
6. Sold Dollar Value		\$28,902	
7. Lost Dollar Value (2-6)		\$15,669	

TABLE 4-9

ROTOR HEAD/CONTROL COST BREAKDOWN

(FY 1980 Data)

	Bearing Cost >\$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted			5,999
2. 1980 Dollar Value			\$873,133
3. Total Sold		736	3,757
4. Total Rejected		334	2,233
5. Percent Rejected (4/1 X 100)		31%	37%
6. Sold Dollar Value		\$52,543	\$646,811
7. Lost Dollar Value (2-6)		\$23,844	\$226,322

TABLE 4-10

HYDRAULIC/ROTARY ELECTRIC/MECHANICAL/AIR FRAME/MISCELLANEOUS COST BREAKDOWN

	Bearing Cost >$60.00 Bore Diameter		
	≤20 mm	>20, ≤50 mm	>50 mm
1. Total Inducted		138	619
2. 1980 Dollar Value		$8,618	$64,309
3. Total Sold		42	332
4. Total Rejected		96	287
5. Percent Rejected (4/1 X 100)		70%	46%
6. Sold Dollar Value		$2,623	$34,740
7. Lost Dollar Value (2-6)		$5,995	$29,569

4.2.1 A/E Engine

Of the total, 14 bearings in the A/E engine are identified as critical by Document MEEI6940 (Appendix C). Of these, gear and pinion support bearings 1-300-031, 1-300-329 and 1-300-335 cost less than $60.00. Because of the relatively low price, these bearings should be considered for refurbishment but not for serious rework. Bearings with part numbers (P/N) 1-300-026, 1-300-027, and 1-300-32?, are employed in the A/E L15 engine only, and the flow of these bearings through the Shop is small. The bearings in the A/E engine considered as rework candidates are shown in Table 4-11.

Part numbers 1-300-032, 1-300-082, and 1-300-115 did not appear in either the ASTORS or in the FY 1980 Bearing Shop flow, and were thus rejected. Part numbers 1-300-406, 1-300-407 and 1-300-408 could not be identified on the engine schematics, and were rejected. The remaining bearings, 1-300-015 and 1-300-176, are included in the final list.

4.2.2 B/E Engine

Only 8 of the total 54 bearings in the B/E engine are designated as critical. The bearing 2-300-005, listed as critical, appears as the No. 2 shaft bearing on the overall B/E schematic, but it seems to have been replaced by 2-300-035 in later versions. This bearing shall not be considered. Furthermore, bearing 2-300-037 applies only to the No. 4 and No. 5 position on the B/E L7B and C. Since no 2-300-037 bearing has been processed in FY 1980, it too shall be omitted at this time. Four bearings, therefore, remain as worth considering. (All other bearings are relatively inexpensive.) See Table 4-12.

Bearing 2-300-006 has a very high reject rate which could possibly indicate rapid failure and could imply inherent difficulty to rework. Inspection of the engine schematic indicates that 2-300-006 is not an extremely critical bearing. This bearing is thus rejected. Part numbers 2-300-034 and 2-300-037 appear to be under phase-out. They exhibit a high reject rate but a low number of new replacement bearings purchased. These are rejected. The remaining bearings (2-300-001, 2-300-011, 2-300-028, and 2-300-035) are included for study.

TABLE 4-11

A/E ENGINE CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
1-300-015	50 B	153.00
1-300-026	110 B	120.00
1-300-027	45 B	64.57
1-300-028	80 R	724.00
1-300-032	25 R	120.00
1-300-082	30 R	123.00
1-300-176	55 R	468.00
1-300-406	30 R	81.55
1-300-407	105 B	599.00
1-300-408	100 R	593.00
1-300-115	?	153.00

TABLE 4-12

B/E ENGINE CANDIDATES

P/N	Bore Size	Unit Price (FY81$)
2-300-001	70 B	367.00
2-300-006*	45 R	179.00
2-300-011	65 BD	762.00
2-300-028	55 BD	223.00
2-300-034**	45 R	123.00
2-300-035	85 R	554.00
2-300-037**	?	401.00

*High reject rate. This may indicate quick failure and difficulty in rework. Also not listed as critical.

**May be under phase-out. High reject rate, but low number of new bearings sold.

4.2.3 C/E Engine

On the C/E engine bearings list, 12 out of 21 bearings are considered critical because they require 100% inspection. Of those critical bearings, the only bearing of significant numbers in ASTORS and the Shop flow, and the only bearing with a high replacement value is 6876009. This is the only C/E engine bearing included in the final list. The C/E bearing candidates are listed in Table 4-13.

4.2.4 A/T Transmission

A total of 31 critical bearings in the A/T transmission are listed in Document MEEI6940. Many of the numbers identified pertain to components such as races, cages, pinions, etc. which, when assembled in unison, form a bearing. Those bearings and the ones with a 100% replacement notation are not listed among the bearings processed through the Shop. In total, 18 bearings processed through the Shop are identified as critical. Using the $60 minimum price, 5 bearings are eliminated, leaving 13 bearings candidates for rework. See Table 4-14.

The largest lot size and lot replacement values are associated with two bearings: 205-040-246 and 204-040-136. The FY 1980 replacement value of the ASTORS count of these bearings was $880,000. No other bearings accounted for a replacement value substantial enough to be included.

4.2.5 C/T Transmission

Based on MEEI6941, all D/T - C/T bearings are critical with the exception of: 206-040-031 which appears to be obsolete, 206-040-034 which is an inexpensive bearing ($6.95 each), and 205-240-406 which requires 100% replacement.

However, of the 15 bearings listed as critical, 8 bearings do not meet the minimum $60 price-per-bearing criterion. The bearings listed in Table 4-15 are candidates for rework.

TABLE 4-13

C/E ENGINE CANDIDATES

P/N	Bore Size	Unit Price (FY 1981$)
6876005	30 mm B	136.00
6876009	40 mm B	74.00
6876010	40 mm B	95.22
6876011	25 mm R	102.00
6859434	40 mm R	151.00
6859436	40 mm B	62.94
6873916	25 mm R	85.95
6873917	30 mm R	111.00
6840137	25 mm R	85.95
6871604	40 mm B	147.00
6889093	30 mm B (split IR)	139.00
6876012		65.13

TABLE 4-14

A/T TRANSMISSION CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
204-040-270	90 R	88.27
204-040-271	120 R	123.00
204-040-310	40 R	71.76
205-040-242	?	86.76
205-040-245	120 BD	658.00
205-040-246	80 BT	622.00
205-040-249	40 R	136.00
212-040-143	35 BD	104.00
212-040-144	35 BD	274.55
212-040-210	40 R-	247.00
212-040-455	25 R-	122.38
212-050-456	40 BD	271.36
212-040-466	30 R-	65.95
204-040-136	—	361.58
204-040-772	—	90.02

Note: Input Drive Quill Triplex Bearing (205-040-246) and unidentified limited life bearing (split inner race angular contact)(204-040-136) are worth $876,600 (85%).

TABLE 4-15

C/T TRANSMISSION CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
206-040-032	80 BD	283.00
206-040-033	85 R-	96.49
206-040-035	31 DRSIG	491.00
206-040-036*	60 B	207.00
206-040-131	25 R-	61.57
206-040-409	10 R-	124.00
206-040-130	55 BT	269.00

*This bearing is an integral part of a transmission gear.

Once again, the only bearing with any significant dollar or unit value in ASTORS or the Bearing Shop flow is bearing 206-040-035. This is the only one included on the final list.

4.2.6 B/T Transmission

The critical bearings in the B/T transmission mentioned in Document MEEI6942 are, with three exceptions, the most numerous and most expensive of all bearing components examined. This does not necessarily imply that the greatest savings can be accrued in this assembly. According to CCAD figures, the rates of rejects are extremely low for these bearings. Hence, the realm for improvement appears to be somewhat limited.

Fifteen critical bearings listed in Document MEE16942 could not be identified in the listing of the bearing flow through the inspection facility. The bearings with P/N's 114DS161, 114D5240, 114DS281, 114DS541, 114DS542, 114DS665, and 114DS668 accounted for the major portion of the total value and were thus included in the rework candidate list. The critical bearings of the B/T transmission are listed in Table 4-16.

4.2.7 D/T Transmission

The critical bearings for this transmission are delineated in Document MEEI6941, together with those for the D/T transmission. At least four bearings identified could not be found on the Bearing Shop's throughput list. These bearings are 369A197, 369A5194, 369A420 and 369A423. Of the critical bearings, 12 were not considered because their cost did not exceed the $60 limit. The remaining bearings are listed in Table 4-17.

Bearing rework at this stage is not applicable for these bearings, since they represent essentially no on-going presence in ASTORS or the Bearing Shop flow. None of the D/T bearings are included in the final list.

4.2.8 Rotor Head/Control

Although no critical list was made available by CCAD for this category of bearings, the Bearing Shop information indicates that the inspection

TABLE 4-16

B/T TRANSMISSION CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
114DS160-1	75 BD	388.00
- 114DS161-1	180 B	2,034.00
114DS162-1	160 R	810.00
- 114DS240-2	120 R	1,774.00
114DS247-1	80 R	236.00
114DS248-1	75 B	95.00
114DS249-1	35 R-	87.43
114DS251-1	90 B	139.00
114DS253-1	30 B	100.00
114DS257-1	60 R	165.00
114DS262-2	110 R	212.00
114DS263-1	30 R-	140.00
114DS274-1	250 B	456.00
114DS275-1	105 B	211.00
114DS280-1	80 BD	396.00
- 114DS281-1	?	1,028.00
114DS282-1	70 DRSR	1,088.00
114DS283-1	150 R-	586.00
114DS284-1	110 BD	958.00
- 114DS541-2	70 B	931.00
- 114DS542-4	75 R	685.00
114DS543-1	60 R	113.00
114DS544-1	60 B	141.00
114DS545-1	75 R-	213.00
114DS548-1	70 B	105.00
114DS549-1	70 R	147.00
114DS550-1	95 B	92.84
114DS571-1	70 R	309.00
114DS517-1	65 B	275.00
114DS574-1	60 R	287.00
114DS576-1	75 R	451.00
114DS641-1	65 B	595.00
* 114DS642-2	70 R	334.00
114DS643-1	55 B	177.00
114DS644-2	55 R	240.00
114DS645-4	95 R-	153.00
* 114DS647-1	60 R	132.00
- 114DS652-1	?	571.00
114DS653-1	?	375.00
114DS661-1	50 R-	63.03
114DS662-1	65 R	134.00
114DS664-1	70 R	595.00
- 114DS665-1	75 R	709.00
114DS666-2	105 R-	304.00
114DS667-1	80 R	550.00
- 114DS668-1,2,3	70 B	476.00
114DS669-2	55 B	151.00
114DS670-1	60 R	500.00
114DS349-1	170 B	1,077.00

*Not listed as critical, but included because of high price.

-Eight bearings indicated are worth $1,505,123 from the ASTORS contents. They are all very expensive bearings, and seven of the eight have very high ASTORS lot values.

TABLE 4-17

D/T TRANSMISSION CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
369A5180		250.00
369A5198-3		139.00
369A5199-3		238.00
369A5258		69.43
369A5432		132.00
369A5433		150.00
369A7003		848.00

The last bearing, although listed as a Bearing Shop throughput candidate shows zero bearings inspected in 1980.

activity in this area is high, as is the rate of rejects. Using the same price criterion, the bearings listed in Table 4-18 should make good candidates for rework. Most of the bearings in Table 4-18 could not be identified by TRW. Further clarification is therefore required before these bearings can be accounted for.

Four bearings are included in the final list due to their high value: 204-011-112, 204-011-409, 204-011-430, and 540-011-449. Bearing 204-011-112 is included, although it apparently is very difficult to refurbish.

4.3 Final Evaluation

The final list of bearings for rework is shown in Table 4-19. Included are part numbers, system identification, FY 1981 (October 1980) units costs (all of which are above $80), number of bearings in both ASTORS and the Shop flow, and the replacement value of these bearings in ASTORS and the Shop flow. Table 4-19 forms the basis for the conceptual approach and feasibility analysis for the inspection and rework system. These bearings have been selected on the basis of the best information available at this time. Because of reasons beyond the author's control, no bearing drawings could be examined for further screening details. It is, however, clear from information subsequently provided by CCAD that certain bearings listed in Table 4-19 will have to be restored by the original manufacturer because of the complexity involved in their rework and assembly. These include bearing numbers: 6876007 (a deep-groove ball bearing with split outer ring); 204-011-430 (double-row ball bearing with intricate cage); 204-011-112 (needle bearing); 114-DS-281 (a double-row gear bearing); and 206-040-035 (double-row gear bearing). Of the remaining bearings, at least five bearings are of the multi-set type (duplex, triplex, and quadruplex). These bearings are particularly vulnerable to cost increases; fortunately, most of these bearings appear to be suitable for in-house restoration as are the other bearings listed.

It is of importance to point out that some of the discarded bearings, particularly those employed in transmissions, are subject to a retirement life limit. It is imperative that this limit is reviewed in view of the latest

TABLE 4-18

ROTOR HEAD/CONTROL CANDIDATES

P/N	Bore Size (mm)	Unit Price (FY81$)
204-011-110	Needle	75.00
204-011-112	Needle	114.00
204-011-409	114 BT	259.00
204-011-430	228 BD	346.00
540-011-128	?	113.00
540-011-449	?	377.00
206-010-443	?	253.00
209-010-443	?	101.00

BD - Duplex Ball Bearing

R- - Roller Bearing - no inner race

R - Roller Bearing

B - Ball Bearing

DRSR - Double Role Spherical Roller
Integral with gear

BT - Triplex Ball Bearing

TABLE 4-19

REWORK SAVINGS DATA

Helicopter System	Part Number	Number of Bearings In ASTORS	Number of Bearings In Shop Flow[1]	FY 1982 Unit Price	Replacement Value In ASTORS	Replacement Value In Shop Flow
A/E	1-300-015	3,798	835	$ 153.00	$ 581,094	$ 127,755
A/E	1-300-176	3,703	510	468.00	1,733,004	238,680
A/E	2-300-001	357	164	367.00	131,019	60,188
A/E	2-300-011	716	77	762.02	545,592	58,674
A/E	2-300-028	1,430	167	233.00	318,890	37,241
A/E	2-300-035	314	125	554.00	173,956	69,250
C/E	6876009	1,019	169	147.00	149,793	24,843
A/T	205-040-246	807	67	622.00	501,954	41,674
A/T	204-040-136	1,084	---	362.00	392,408	---
C/T	206-040-035	775	194	491.00	380,525	95,254
B/T	114-DS-161-1	65	4	2,034.00	132,210	8,136
B/T	114-DS-240-2	272	41	1,774.06	482,528	72,734
B/T	114-DS-281	32	43	1,028.00	32,896	44,204
B/T	114-DS-541-2	384	142	931.00	357,504	132,202
B/T	114-DS-542-4	156	56	685.00	106,860	38,360
B/T	114-DS-652-1	104	21	571.00	59,384	11,991
B/T	114-DS-665-1	169	20	709.00	119,821	14,180
RH/C[2]	114-DS-668-1,2,3	256	35	776.00	198,656	27,160
RH/C	204-011-112	1,214	629	81.73	99,220	51,408
RH/C	204-011-409	583	257	259.00	150,997	66,563
RH/C	204-011-430	636	398	346.00	220,056	137,708
	540-011-449	686	67	377.00	258,622	25,259
	TOTALS	18,560	4,021		$7,126,989	$1,383,414

[1]Average of Annual Flows for CY 1978, FY 1979 and FY 1980.

[2]Rotor Head/Control

Source: CCAD Bearings Shop and ASTORS data files

progress made in the production of cleaner bearing steels and in the understanding of the bearing lubrication process. To demonstrate what this could do to savings, let us examine the history of bearing No. 114-DS-542. In FY 79, 95% of these bearings were rejected. The rates of rejects in FY 80 dropped to zero. This occurred primarily because of lifting of the 1,200-hour replacement requirement.

Referring to Table 4-19, the main savings potential lies in the ASTORS and in Shop annual reject flow replacement values. The question of how to turn the rejects into assets is addressed in the following sections.

5.0 DISCUSSION OF RECOMMENDED IMPROVEMENTS

From the data so far presented, it is clear that the present bearing overhaul facility meets the minimal needs of the Corpus Christi Army Depot. It is also clear that an appropriate bearing refurbishment system could significantly enhance the mission readiness of CCAD and do it in a way that provides operational savings. To discern an appropriate system, the overall mission of the bearing overhaul facility and those elements necessary to carry it out must be considered.

The mission of the Bearing Refurbishment Center includes the requirement to provide quality bearings in a timely fashion and in sufficient quantity to allow the aircraft overhaul facility to fulfill its mission. A complete bearing diagnostic and refurbishment system as shown in Figure 5-1 dictates the need for three major elements. The first of these is a bearing diagnostic subsystem; the second, a bearing overhaul and rework subsystem; and the third, an inventory management system. As shown in Figure 5-1, new and used bearings enter the bearing diagnostic subsystem for evaluation and either are put back in service, discarded, or forwarded to the rework facility to correction whatever flaws may exist. Such bearings are then inspected before being returned to service.

5.1 Bearing Diagnostic Subsystem (BDS)

5.1.1 Need

As indicated earlier, the Corpus Christi Army Depot Bearing Facility typically processes 400 different bearing types with an annual volume of approximately 200,000 bearings per year. Of these, approximately 30% are rejected as being unfit for service in their present condition. These unfit bearings have been identified through a testing procedure that includes both dimensional checks and functional tests.

5.1.2 Limitations

There are a number of limitations in the current system that relate primarily to reliance on a limited pool of skilled inspectors. The quality of the output suffers through the occasional misclassification errors, which

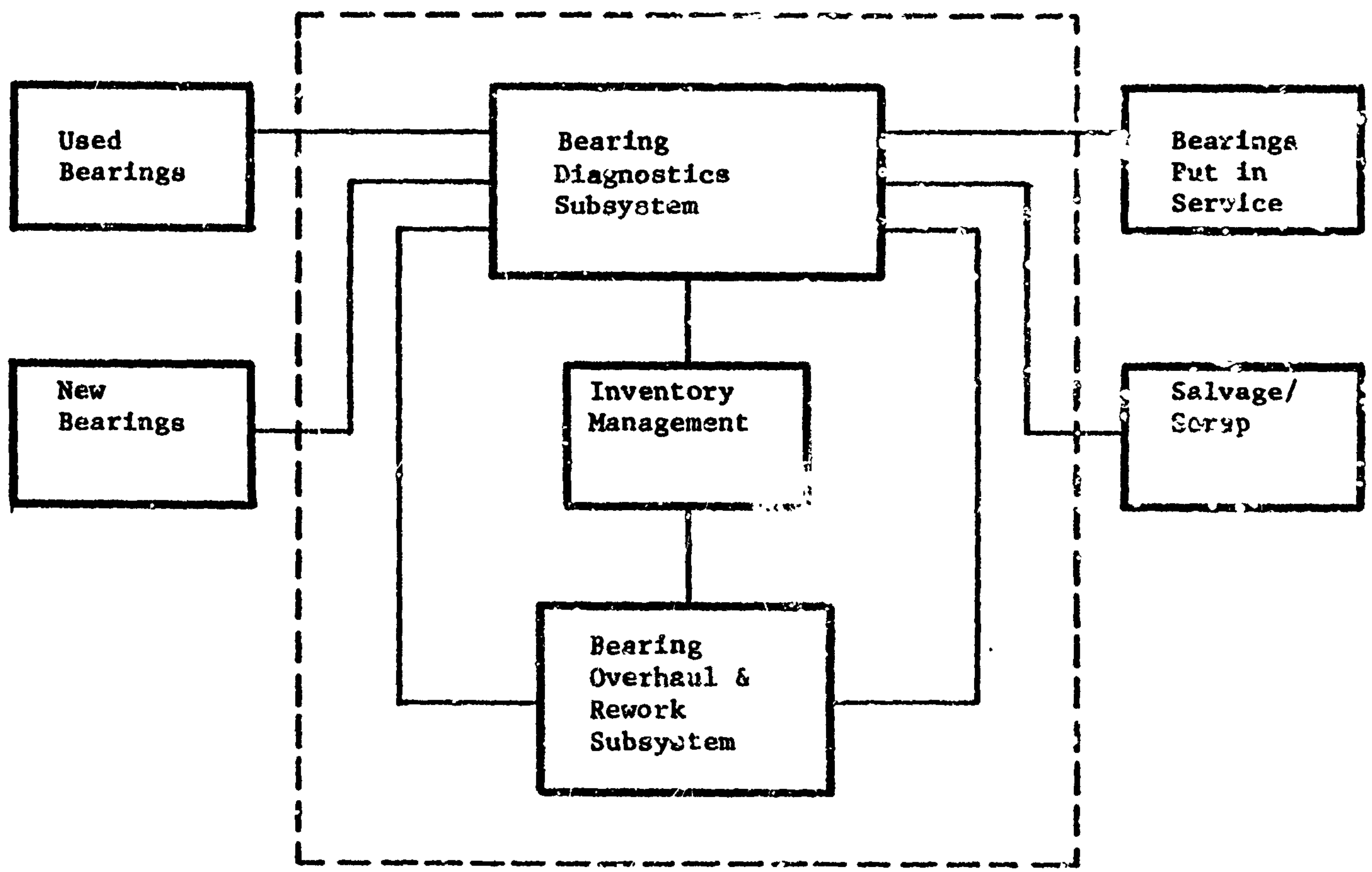

Fig. 5-1 Bearing Refurbishment System

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arise because of the human errors possible in the labor-intensive testing. This is particularly true in diagnostic testing, where the inspectors judge the bearing performance as they sense its response to a rotating spindle against which the bearing is pressed. A second limitation relates to the throughput, which, although adequate for the current requirements has very limited expansion capability because of the reliance on a skilled inspector. Lastly, the inspection techniques provide only minimal assistance to the rework operation in terms of insight as to the cause of the rejection. Better diagnostic aids clearly would speed the rework.

5.1.3 Proposed Improvement

The previous section indicates a number of opportunities to improve the current system. Clearly, one of the more attractive opportunities relates to automating the functional tests and as many of the dimensional tests as appear appropriate. This will reduce classification errors and enhance quality. Diagnostic information can readily be made available to guide rework efforts. Further, automating the system in a modular fashion provides the opportunity for the system to grow in response to higher throughput needs and incorporates the flexibility to respond to different bearing requirements, should and when these become appropriate. In addition, with such a modular approach, the reliability of the overall system can be significantly enhanced. A further improvement which would enhance the productivity relates to controlling the flow of bearings through the BDS. Limited batch processing and response to the needs of critical elements can be accomplished with a more automated system.

5.1.4 MTI Contribution

Mechanical Technology Incorporated has been active in this area for many years and has developed several pieces of equipment which are uniquely suited to this particular challenge.

To eliminate the human factor in functional inspection, MTI has developed and perfected a new technique. This effort resulted in successful demonstration of the capability of this technique to differentiate between directly reusable and repairable or scrap bearings. This demonstration

was performed on two bearing analyzers (BDI-100™), built for CCAD to inspect ball and roller bearings. The results of the performance verification of the machine have been reported in Reference [13].

Along with the BDI-100™, MTI has developed a fluid-film measuring device known as the Asperitac™. The Asperitac™ is, basically, a highly sensitive instantaneous resistance reading meter. When a small voltage is applied across the inner and outer races of the bearings, the resistance changes which occur during operation are counted and integrated utilizing a preset threshold and a predetermined time interval. The threshold, or discrimination level, is selected to provide an indication of the bearing's capability to: 1) develop a full film capable of separating the rolling elements from the races, and 2) under boundary lubricating conditions, to give a numerical display of the interaction between asperities. This numerical readout can also be utilized to determine the acceptability of the bearing surface finish.

The MTI rolling element bearing analyzer (BDI-100™) and Asperitac™ were developed specifically to eliminate the highly subjective personal judgement required by bearing inspectors. The system logic employed in screening bearings using this equipment renders itself suitable for computerization and further automation. The objective of any automated or computer-controlled design implementations would be to realize a greater inspection throughput rate, to increase system data analysis capability, and to improve reliability. To apply this concept to the CCAD solution, some application engineering is required. Specifically, an improved bearing loading and fixturing system must be designed to reduce the system impact of the time associated with unloading the bearings. With the current fixturing, the inspection of a double-acting thrust ball bearing, which requires inversion of the bearing, may take up to 5 minutes. On the other hand, single-acting bearings have been timed at 1-1/2- to 2-minute intervals.

MTI is also currently developing new diagnostic equipment based upon MTI's CD320 Fotonic™ sensor. The development, which is an invention of G. Phillips of the Naval Research and Development Center, is being sponsored by the U.S. Navy.

5.2 Bearing Overhaul and Refurbishment Subsystem (BORS)

5.2.1 Need

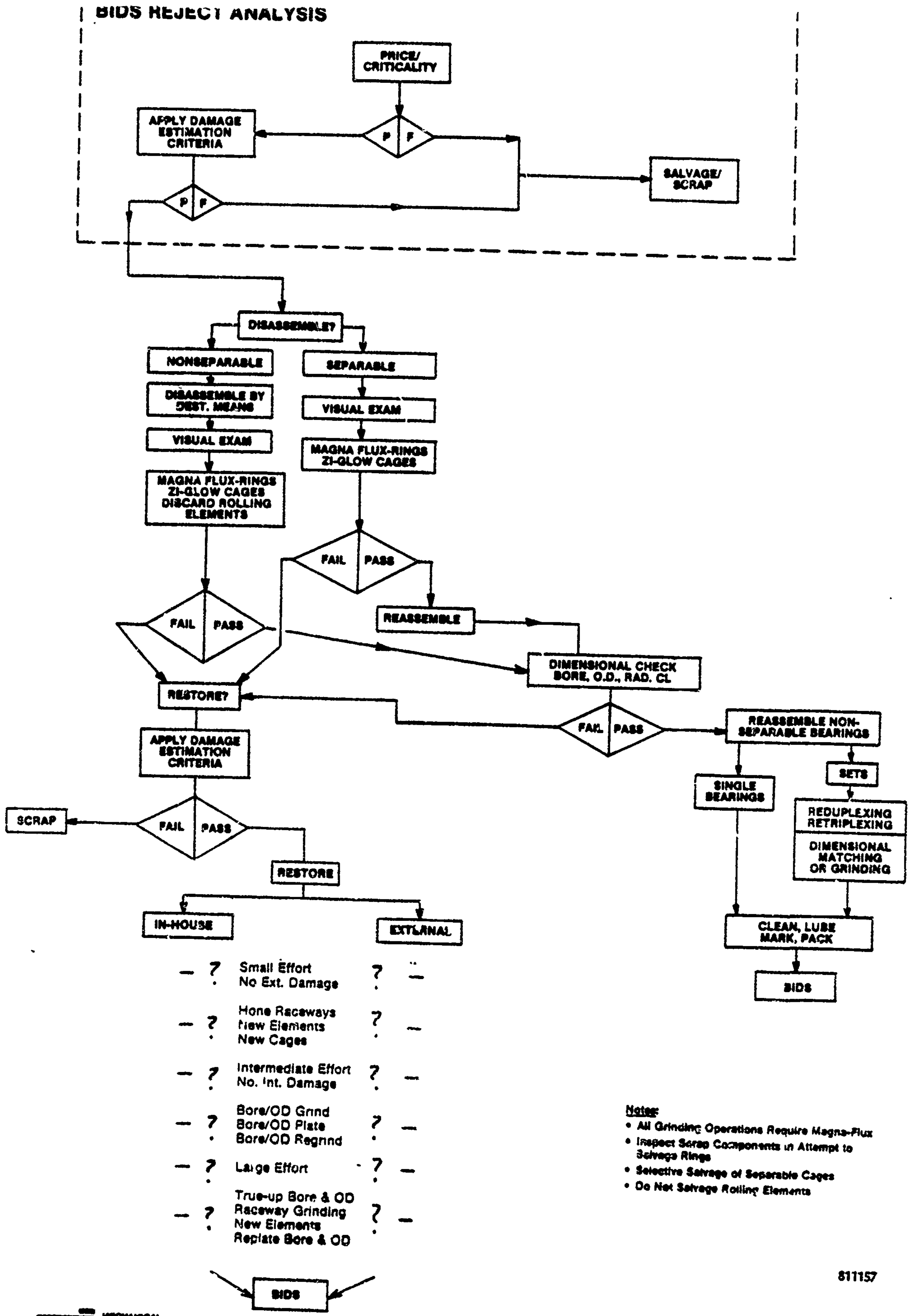
The current workload described earlier implies that the 30% reject rate is equivalent to 60,000 bearings which cannot be returned for use. These bearings must either be replaced or, if the damage on them is only minimal, must be reworked such that their dimensional and functional characteristics are acceptable and they can be returned to service.

5.2.2 Limitations

The current system has very limited internal refurbishment capability and must therefore seek outside help with bearings that are damaged. This causes problems of cost and availability. The cost of replacement bearings has been escalating very rapidly and reflects not only limited quantity purchases but, more importantly, a significant premium for quick delivery. Even with such premiums, however, certain replacement and refurbishment opportunities are not available in the time frame required for CCAD's operational readiness. For these, bearing availability has become a serious concern. In addition, there is a general concern over the utilization of strategic materials which, under current practices, is not as effective as it might be.

5.2.3 Proposed Improvements

In many cases, bearings have been rejected for faults which can be corrected by polishing, regrinding, or replacing some critical elements. Currently, little refurbishment, except for some polishing, is done internally. It would appear very attractive to provide expanded in-house machining capability in order to rework selected sets of bearings chosen because of the cost and criticality of these bearings. Figure 5-2 indicates how such a restoration facility might be configured and indicates some of the currently outstanding questions as to where the restoration activities can be accomplished most cost effectively (i.e., internally or externally).



MECHANICAL TECHNOLOGY INCORPORATED

Fig. 5-2 Restoration Facility Flow Chart

5.2.4 TRW Contribution

The equipment required for the restoration of bearings consists of fairly standard tools. A close examination of the space available in and around the Bearing Shop, as well as in the grinding areas, indicates ample room for all the equipment requirements arrived at in this study. Configuring these tools in a cost-effective way to meet the particular requirements of the Corpus Christi situation requires an intimate knowledge of the techniques for fabricating and reworking bearings. The TRW Bearing Division has had such experience. TRW is the fabricator of a full spectrum of bearings for the U.S. military, particularly for the engines of interest to the Corpus Christi Army Depot. In addition, TRW operates bearing rework facilities for the commercial airlines. MTI is very pleased, therefore, to offer the above recommendation for an overall facility as proposed by TRW, as an associate, for consideration in the implementation of this bearing refurbishment system under discussion.

5.3 Inventory Management System (IMS)

5.3.1 Need

Effective employment of the bearing refurbishment system requires information and a set of management tools. To assure proper responsiveness, information and control is needed concerning details of bearing work flow within the inspection and overhaul subsystems. To increase the cost effectiveness of the system, data must be assembled and collected regarding the subsystem performance of both the BDS and the BORS. Further, an appropriate data base must be constructed to determine bearing usage rate for cost-effective purchasing of replacements and to provide the ability to identify incipient bearing problems in specific applications.

5.3.2 Limitations

The current practice at CCAD is characterized by the relative absence of any management information systems. Consequently it is very difficult both to achieve the mission objectives indicated and to tie into other data bases such as that maintained by TSARCOM. The limitations of the current system lead to very costly purchases of replacement bearings because purchasing is relatively unscheduled and with high priority associated with prompt turn-around, for which a rather high premium is now being paid.

5.3.3 Proposed Improvements

Most of the appropriate improvements are part of a normal inventory management system and for this application would have two major elements: an inventory control system and a historical data base. The inventory control system relates to the Shop floor and permits control through information concerning the current backlog of bearings awaiting inspection (the work-in-process inventory), to include the status and test records of bearings in either of the other subsystems (the finished good and the raw material components). Furthermore, this inventory control system should develop and monitor performance indicators for each subsystem, as well as for individual test or repair modules.

The historical section should accumulate data on the volume and reject rate of each processed bearing type. Where possible, this should be correlated with usage in specific equipment (transmissions, or engines in particular aircraft types) so that field experience can be properly used in both design and spare-parts ordering. Also included would be records on bearings whose serial numbers make it possible to maintain an ongoing record. These records, of course, need to be properly interfaced with other relevant data bases such as that in TSARCOM. Finally, the data base for forecasting and purchasing replacement bearings would be maintained in the historical section. Economic and intelligent purchasing requires knowledge of the quantity, price, and lead time of recent buys, as well as the predicted quantities based on correlations of usage with, for example, fleet size.

5.3.4 MTI Contributions

MTI has considerable experience in data base management and application in production environments. In conjunction with the General Electric Computer Operations, MTI developed several business software packages which included inventory and control management elements. MTI currently offers test and diagnostic systems used in production environments for quality-control purposes; these systems have many elements requiring comparable data base management skills as well as computer control skills. In addition, numerous MTI personnel have management experience in the development of point-of-sales systems, factory data collection systems, and other systems with

similar data processing requirements. An example of such a system is described in Section 6.0, which delineates a computer code specifically developed to aid in the execution of this program.

5.4 Summary

As this discussion has indicated, the potential for improvements exists in the areas of readiness and economics. Readiness can be enhanced by increased throughput, by higher quality output, and by more reliable systems, all of which yield greater availability of bearings for the aircraft overhaul facility. The economic opportunities are related to the operational savings made possible through the cost of replacement bearings saved through the rework facility, as well as through the ability to control costs more effectively both in operation and in purchasing, utilizing management information systems. MTI feels that these potential improvements can be achieved using a system which is modular, which employs distributed capabilities for reliability, and which is sufficiently self-contained to assure as much readiness as is desired. The code discussed in the next section can serve as a basis for improved inventory management and control.

6.0 COMPUTER-AIDED INVENTORY MANAGEMENT

One of the very important aspects of improved bearing inventory management is the availability of quick and reliable information pertaining to the state of the bearing in process and in storage. Although fairly detailed Bearing Shop data was provided by CCAD to MTI for the purpose of performing the analysis described in the preceding sections, most of this data was in hand-written form, indicating the absence of a comprehensive computerized inventory system. Another sign of, perhaps, inadequate inventory control is the variation in price increases for various bearings as described in Table 6-1 . It is apparent that CCAD could enormously benefit from the presence of a comprehensive inventory control system. The foundation for such a system was laid within the scope of this program in the form of a computer code. The need for it arose primarily because of the narrow time frame within which the economic analysis was to be performed.

6.1 Description of Fundamental Computer Code

The computer code developed for this program has the built-in capability for data storage, retrieval, and segregation.

The inventory code assigned an MTI designation PN903 is executed in an interactive mode, responding to the user's requests. The following options are currently available to the user:

I. Print listings of the following files:

- IDENT FILE (Identification file), sorted as specified by the user. The major parameters of interest can be chosen for the sort from the following list:

  Location Code
  Part Number
  National Stock Number
  Vendor Part Number
  Type of Bearing (Roller or Ball Bearing)
  Separable or Non-separable
  Bore Size
  Lubrication
  Number in a set
  Criticality
  Unit Cost

TABLE 6-1

ANNUAL CHANGES IN UNIT COST
FOR NEW REPLACEMENT BEARINGS
(Bearings Recommended for Rework)

Bearing Part Number	1975 Unit Price ($/Bearing)	Annual Percentage Increases					1980 Unit Price ($/Bearing)
		1975-1976[1]	1976-1977[1]	1977-1978[1]	1978-1979	1979-1980	
1-300-015	89.77	-3.1	-3.1	-3.1	-1.2	+90.9	153.00
1-300-176	116.00	+3.1	+3.1	+3.1	+5.5	+249.3	468.00
2-300-001	124.00	+23.6	+23.6	+23.6	+56.0	+0.5	367.00
2-300-011	235.00	+11.2	+11.2	+11.2	-0.6	+137.1	762.00
2-300-028	102.00	+16.4	+16.4	+16.4	+29.2	+7.2	223.00
2-300-035	389.00	-1.9	-1.9	-1.9	+41.3	+7.2	554.00
6876009	67.38	+22.5	+22.5	+22.5	+4.8	+13.1	147.00
205-040-246	501.00	+21.3	+21.3	+21.3	-35.4	+7.6	622.00
204-040-136	205.00	-1.3	-1.3	-1.3	+61.3	+13.7	361.58
206-040-035	413.00	+4.7	+4.7	+4.7	-2.3	+6.0	491.00
114-DS-161-1	981.00	-3.4	-3.4	-3.4	+116.3	+7.1	2,034.00
114-DS-240-2	660.00	+7.1	+7.1	+7.1	-4.3	128.3	1,774.00
114-DS-281	817.00	+6.6	+6.6	+6.6	-2.3	+6.2	1,028.00
114-DS-541-2	331.00	+11.9	+11.9	+11.9	+38.6	+44.8	931.00
114-DS-542-4	737.00	-3.3	-3.3	-3.3	-2.4	+6.2	685.00
114-DS-652-1	265.00	+1.6	+1.6	+1.6	+91.7	+7.1	571.00
114-DS-665-1	308.08	+22.2	+22.2	+22.2	+6.6	+18.4	709.00
114-DS-668-1,2,3	351.00	+11.5	+11.5	+11.5	-2.3	0.0	476.00
204-011-112	42.17	+39.4	+39.4	+39.4	0.0	0.0	114.10
204-011-409	147.00	-3.3	-3.3	-3.3	+96.1	0.0	259.00
204-011-430	186.00	-4.8	-4.8	-4.8	+88.6	+16.1	346.00
540-011-449	99.31	+39.4	+39.4	+39.4	+15.6	+21.2	377.00

[1] Based on 1975 and 1978 prices, the levelized annual percentage change on a compounded basis over the three-year period.

Source: CCAD Bearing Shop Data

- ASTOR FILE (Automated Storage and Retreival System)
- BSHOP DATA (Bearing shop data)
- BEAR INDEX (Bearing shop index)

} Listed by Page Number, in ascending order

II. Print complete inventory listings with quantity and cost sub-totals, according to specifications by the users.

- The user may choose an inventory of the following:

  (1) Data in ASTORS
  (2) Data in Bearing Shop
  (3) Combined data in ASTORS and bearing shop

- Quantity and cost sub-totals may be chosen from the following parameter list:

  (1) Location Code
  (2) Part Number
  (3) Quantity
  (4) Year/Quarter
  (5) Source
  (6) Status
  (7) Condition Code
  (8) Cost

- The user must specify a unit cost cutoff value. Bearings with a unit cost <u>less</u> than the designated cutoff value are <u>omitted</u> in the inventory list.

III. Print an inventory listing for one or more specific parameters with quantity and cost sub-totals.

IDENT FILE Description

Identification File Format

Columns	Contents	Format
3- 4	Location Code	A2 (Alphanumeric)
6-24	Part Number	4A4, A3 (Alphanumeric, left-justified)
25-40	National Stock Number	4A4 (Alphanumeric, left-justified)
41-55	Vendor Part Number	3A4, A3 (Alphanumeric, left-justified)

- ASTOR FILE (Automated Storage and Retreival System)
- BSHOP DATA (Bearing shop data)
- BEAR INDEX (Bearing shop index)

} Listed by Page Number, in ascending order

II. Print complete inventory listings with quantity and cost sub-totals, according to specifications by the users.

- The user may choose an inventory of the following:

  (1) Data in ASTORS
  (2) Data in Bearing Shop
  (3) Combined data in ASTORS and bearing shop

- Quantity and cost sub-totals may be chosen from the following parameter list:

  (1) Location Code
  (2) Part Number
  (3) Quantity
  (4) Year/Quarter
  (5) Source
  (6) Status
  (7) Condition Code
  (8) Cost

- The user must specify a unit cost cutoff value. Bearings with a unit cost less than the designated cutoff value are omitted in the inventory list.

III. Print an inventory listing for one or more specific parameters with quantity and cost sub-totals.

IDENT FILE Description

Identification File Format

Columns	Contents	Format
3- 4	Location Code	A2 (Alphanumeric)
6-24	Part Number	4A4, A3 (Alphanumeric, left-justified)
25-40	National Stock Number	4A4 (Alphanumeric, left-justified)
41-55	Vendor Part Number	3A4, A3 (Alphanumeric, left-justified)

IDENT FILE Description (Cont'd)

Columns	Contents	Format
57	Type of Bearing	A1 (Alphanumeric)
59	Separable or Non-Separable	A1 (Alphanumeric)
60-64	Bore Size (mm)	I5 (Integer, right-justified)
66	Lubrication (O or G)	A1 (Alphanumeric)
68	Number in a Set	I1 (Integer)
70	Criticality (0 = not critical) (1 = critical)	I1 (Integer)
71-73	Type: NIR = no inner ring DR = double ring IG = integral gear	A3 (Alphamumeric, left-justified)
74-80	Unit Cost	F7.2 (Real, right-justified)

ASTOR FILE Description

(Automated Storage and Retrieval System Data)

Data File Format:

Columns	Contents	Format
1- 5	Page Number (identifies page of ASTOR data, as received)	I5 (Integer, right-justified)
7-26	Part Number	5A4 (Alphanumeric data, left-justified)
51-55	Data Inducted (Year, day)	I2, I3 (Integers, right-justified with leading zeroes)
63-64	Condition Code	A2 (Alphanumeric data)
66-75	Quantity: Number of Bearings Inducted	I10 (Integer, right-justified)

BEAR INDEX Description

Bearing Shop Index Format

Columns	Contents	Format
1- 5	Page Number, Identifies Bearing Shop Data, as Received	I5,(Integer, right-justified)
6-10	Year	I2, (Integer, right-justified)
11-15	Location Code	A2, (alphanumeric)

BSHOP DATA Description

Bearing Shop Data Format

Columns	Contents	Format
1- 5	Page Number (identifies page of bearing shop data, as received)	I5 (Integer, right-justified)
7-26	Part Number	5A4 (Alphanumeric data, left-justified)
27-46	Additional Characters to descripe the part number	
48-49	S in column 49 for set or HS in column 48 to 49 for half-set	A2 (Alphanumeric)
51-56	Quantity of Bearings inducted	I6 (Integer, right-justified)
57-62	Quantity of Bearings sold	I6 (Integer, right-justified)
63-68	Quantity of Bearings rejected	I6 (Integer, right-justified)
69-74	Reject Rate, percent	F6.1 (Real, right-justified)
75-80	New Bearings Sold	I6 (Integer, right-justified)

This code can be expanded to encompass the conventional military codes, provide for a closer bearing identification by subassembly, and maintain a record of in-flow, out-flow, and bearings remaining in the inventory.

If approached properly, the code offers an opportunity to incorporate increased bearing inventory management techniques into the Bearing Shop

operations and to serve as an early warning system should a bearing shortage or unusually high prices develop. For example, Table 6-1 shows the fluctuations in unit price for the 22 bearings selected for rework over a 5-year period from 1975 to 1980. The unit prices for 1975 and 1980 are also shown. There is a wide fluctuation, both up and down, in unit prices over the period, with the general trend towards significant increases. Percentage changes are based on unit cost data for the years 1975, 1978, 1979 and 1980.

The effects shown, especially large increases and decreases, are due to several factors plus inflationary pressures. These factors include lot size, the rush nature of the orders, and change in bearing design. Such effects can be further studied, utilizing the inventory management program, to arrive at solutions to this problem.

6.2 Summary

It is highly desirable that this additional work, necessary to upgrade the code generated within the scope of this program, be funded as soon as possible, inasmuch as it will provide an important tool for exact determination of bearing cost, rework, and inspection requirements, in addition to maintaining an on-going balance of inventoried bearings.

7.0 ECONOMIC ANALYSES OF ALTERNATIVE SYSTEMS

Section 4.0 identified the significant opportunity that 22 critical bearing types could easily generate an annual flow of 8,000 bearings per year for reconditioning. These bearings are critical as parts and are economically important as a potential savings in replacement costs. They constitute a happly instance where readiness and economics go hand in hand. More generally, this is not so; i.e., the goals of readiness and economics lead in different directions.

The mission of the CCAD Bearing Shop includes both the economics and the readiness goals. The appropriate proportioning of these goals is a critical management decision which must be periodically reviewed in the light of changing circumstances. These considerations suggest that the present study would be most helpful if it considered several alternatives: one focused on the economic goal and another, on the readiness goal. However, to provide a framework for understanding the replication components in these two systems, a third or baseline system would also appear helpful. Therefore, three alternatives will be considered:

- Baseline System - Consisting of one element of each piece of equipment required to provide a self-contained bearing refurbishment center.
- Economics System - Containing enough redundant equipment to accommodate the work flow associated with the critical set of bearings identified in Section 4.0.
- Readiness System - Containing additional redundancies and other supporting equipment to extend readiness through increases in responsiveness, throughput, reliability, and quality.

Each system is characterized by the overall system diagram shown in Figure 7-1. The systems embodying this refurbishment process are envisioned as occurring in parallel with the current processing and refurbishment activities of the CCAD Bearing Shop. However, the proposed systems will address only a portion of the bearing flow currently processed in the Bearing Shop.

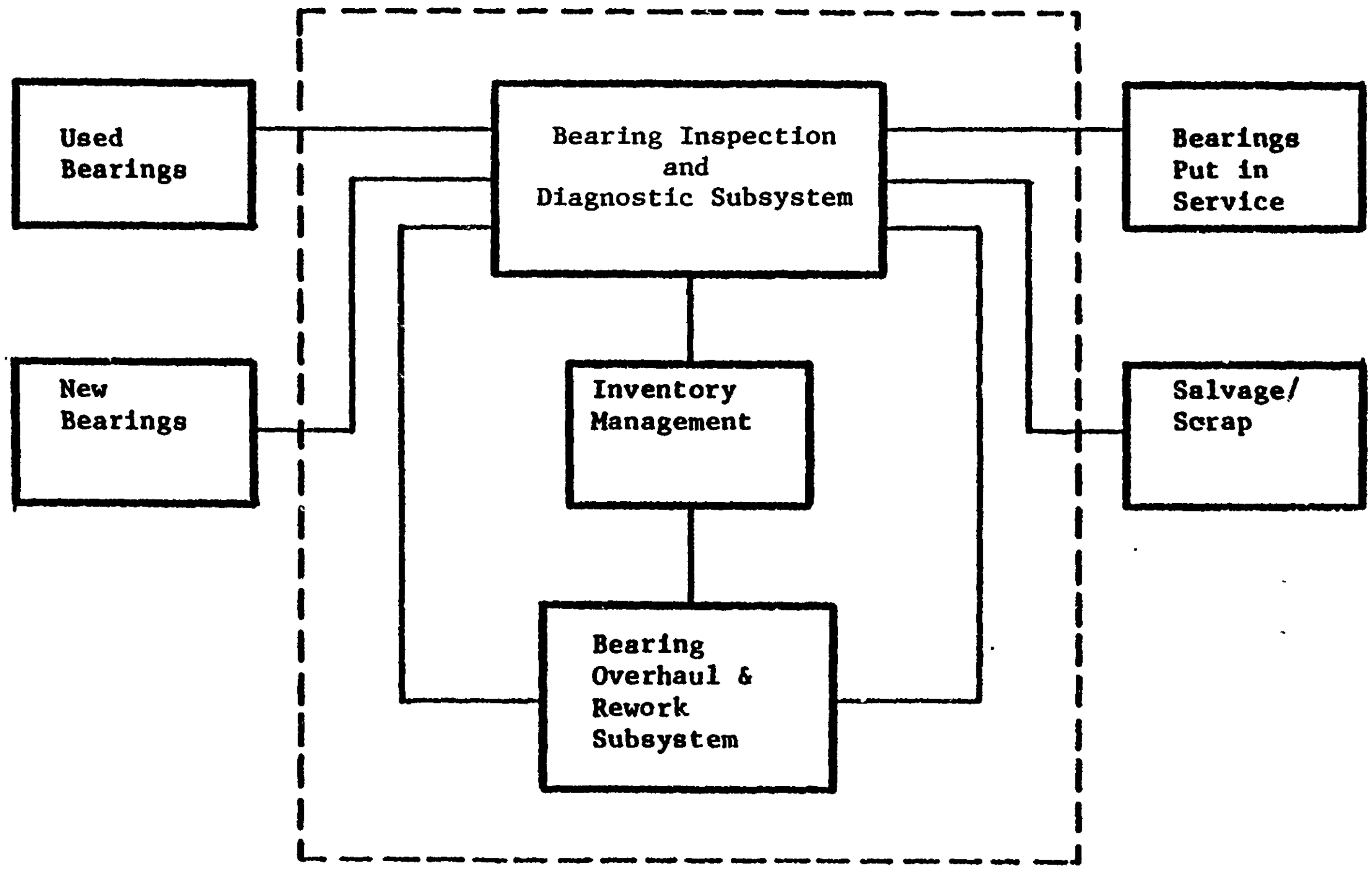


Fig. 7-1 Bearing Refurbishment System

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In the implementation phase, the input will consist of bearings rejected in the normal course of inspection.

Consequently, the system economics will be performed on an incremental basis. The costs and net benefits will be analyzed by customary techniques which follow from other considerations of systems where advanced techniques in bearing diagnostics, effective tools in inventory management, and substantive reconditioning capabilities are used to provide net benefits both in the form of savings (in the purchase of replacement bearings) and also in the form of enhanced readiness.

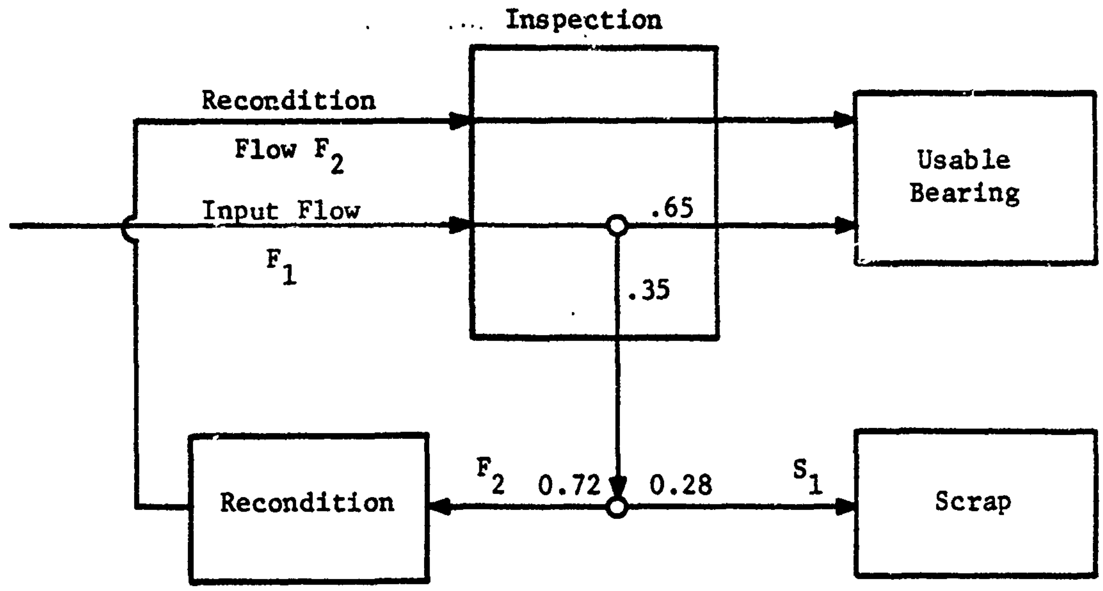
7.1 Baseline System

The baseline system is that minimum configuration of equipment required to provide the necessary functions. As will be indicated, the system seems capable of handling approximately 3,500 bearings per year through the reconditioning subsystem, all of which could be drawn from the ASTORS inventory.

7.1.1 Nonrecurring Costs

The nonrecurring costs fall into three categories and are described in the following paragraphs. These categories relate to the diagnostic subsystem, the reconditioning subsystem, and the associated training.

7.1.1.1 Diagnostic Subsystem. The key to the automation of the diagnostic subsystem is the test equipment which provides a diagnostic assessment of bearing condition. The automated inspection envisioned is an adaptation of MTI's bearing diagnostic equipment, the BDI-100, and a companion piece of equipment, the Asperitac™. These equipments need to be adapted to the present system and process requirements. Of particular importance are the material handling aspects: adaptors for different bearings must be designed together with a test stand so as to permit the necessary inspection flow. As seen in Figure 7-2, the normal work flow, the inspection subsystem must process about five times as many bearings as the reconditioning subsystem. (In the case of ASTORS bearings or bearings normally rejected at inspection elsewhere, the preliminary screening has already occurred, so the ratio is only 2:1.) This implies that, for the initial phase, the diagnostic system



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Inspection Flow = F

$$F = F_1 + F_2$$

$$F_2 = F_1 \times 0.35 \times 0.72 = 0.25\ F_1$$

$$F = 1.315\ F_1$$

$$= 5.0\ F_2$$

$$\text{Scrap} = S_1$$

$$= F_1 \times 0.35 \times 0.28 = 0.10\ F_1$$

$$\text{Usable } U = U_1 + U_2$$

$$= 0.65\ F_1 + F_2$$

$$= 0.9\ F_1$$

Fig. 7-2 Relation of Flow Rates

needs a throughput capability of 7,000 bearings per year and ultimately would require a capability to process 17,500 units per year. A system sized at approximately 20,000 units per year has been used for costing purposes.

The second element in the diagnostic subsystem is the control system which consists of a minicomputer, a work station, a printer, and associated memory such as disc or tape units. Communication with floor equipment is necessary and is provided for. These communication requirements and floor equipment, including remote work stations at test and qualification stands, is sized to accommodate an input diagnostic load of about 20,000 bearings annually.

Routines to guide and record the bearing inspection and diagnosis must be established and working programs must be provided to expedite the processing. Specific instructions must be provided for the test and inspection of particular bearing types on each of the automated test machines, together with the performance criteria and diagnostic algorithms. Funds discussed here include those for the initial setup, debugging, and establishment of a procedure to add new bearings to the set of bearings that can be automatically inspected.

Central to the economic performance of the system are those management tools which permit effective control of the total bearing inventory. These begin with the package to control the inventory in the Shop (viewing it as a factory) and ordering the Shop priorities in light of the larger inventory managment requirements of the entire overhaul facility. Several data bases need to be maintained and utilized in upgrading quality, identifying potential problems and shortages and providing effective forecasting for the acquisition of spare parts and replacement bearings.

These units are somewhat modular in terms of the software managment systems and some of the special supporting hardware. Bearing flows through the diagnostic subsystem of about 20,000 per year are provided for.

The subsequent processing of acceptable bearings, including cleaning, disassembling, dimensional checks, preservation and packaging, is the same for these special bearings as for any bearings processed by the CCAD Bearing Shop and would be treated similarly. Consequently, this final processing does not represent an incremental cost.

7.1.1.2 Refurbishment Subsystem. The details of the bearing processing and the refurbishment subsystem are set forth in Table 7-1. Provision must be made for layout in the plans for the rework facility and preparing the documention describing the requisite processing through the restoration facility of each of the new bearing types. This has been included in Table 7-2 which summarizes the nonrecurring costs.

7.1.1.3 Associated Training. Provision has been made for the initial training of personnel who will operate both subsystems and for the cost of supervising the system during its initial period.

7.1.1.4 Summary. All nonrecurring costs have been summarized in Table 7-2, which also indicates the basic throughput capability of the different components. For ease in comparison, the throughput capabilities have been given in terms of the annual equivalent throughput which the reconditioning subsystem can handle. These throughputs have been approximated, assuming a historical mix of bearing and rework needs. The total nonrecurring cost for the baseline system is $3.13 million.

7.1.2 Recurring Costs

The key element in assessing the recurring costs is the size of the rework flow capable of being supported by the baseline restoration facility. Based on the data set forth in Table 7-3 and 7-4, it appears likely that, with the historical mix of faults and remedies*, the baseline system could process approximately 3,500 bearings per year. Consequently, all subsequent computations relative to the baseline system utilize this number.

*Example - only about 70% of the bearings to be refurbished require raceway honing.

TABLE 7-1

CCAD BEARING REFURBISHMENT BY ACTIVITY TIMES AND INCREMENTAL CAPITAL COSTS FOR BASIC SUBSYSTEMS

Refurbishment Category by Inspection and Extent of Rework Required	Step	Times (min)		Incremental Capital Costs[1]	
		Process[2]	Setup[3]	Item	Cost (1980 $)
Passes through simply (around 200,000 bearings per year handled)	Clean	2	--	(See Table 7-2)	
	Examine	1	--		
	Dynamic Test		5		
	Surface Test	3	5		
	Dimensional Test	2	--		
	Preserve & Package	2			
	Totals	10	10		
Ok, but requires disassembly	Through dimensional test	10	20		
	Disassemble	1-10	--	(Drill press with simple fixturing)	1,500
	Visual Exam	5	--		
	Cleanup	1	--		
	Reassemble	3-10		(Small press with tooling	9,000
				vises and table with fixturing)	3,300
	Dimensional check	2			
	Preserve & Package	2			
	Totals	24-40	20		13,800

[1]Installed costs minus training, unless otherwise noted.

[2]Per bearing.

[3]Per lot.

TABLE 7-1 (Cont'd)

CCAD BEARING REFURBISHMENT BY ACTIVITY TIMES AND INCREMENTAL CAPITAL COSTS FOR BASIC SUBSYSTEMS

Refurbishment Category by Inspection and Extent of Rework Required	Step	Times (min) Process[2]	Setup[3]	Incremental Capital Costs[1] Item	Cost (1980 $)
Disassembly and race honing required	Through dimensional test	10	20		
	Disassembly	1-10			
	Visual Exam	1			
	Hone Races	10	60	(Honing machine with tooling)	150,000
	Check rolling elements[4] 4	10			
	Magnaflux	2			
	Demag and clean	2			
	Check cage & zyglow	2			
	Reassembly	3-10			
	Clean	1			
	Dimensional check	3			
	Preserve & package	2			
	Totals	47-63	80		150,000

[4]Probably replace rolling elements.

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TABLE 7-1 (Cont'd)

CCAD BEARING REFURBISHMENT BY ACTIVITY TIMES AND INCREMENTAL CAPITAL COSTS FOR BASIC SUBSYSTEMS

Refurbishment Category by Inspection and Extent of Rework Required	Step	Times (min) Process[2]	Times (min) Setup[3]	Incremental Capital Costs[1] Item	Incremental Capital Costs[1] Cost (1980 $)
Grinding and replating of bore and OD required	Through dimensional check	10	20		
	Disassembly	1-10			
	Visual Exam	5			
	Rough bore and OD check	2		In process inspection Equipment (gages master, etc.)	10,000
	Rough grind bore	5	30		
	Rough grind OD	5	30	Bore grinder	230,000
	Chrome plate bore and OD	30		Common grinder tooling	20,000
	Regrind bore	10	60		
	Regrind OD	10	60	OD grinder	200,000
	Magnaflux	2			
	Demag & clean races	2			
	Zyglow & inspect cage	2			
	Reassembly	3-10			
	Clean	1			
	Dimensional check	3			
	Preserve & package	2			
	Totals	93-109	200		460,000

TABLE 7-1 (Cont'd)

CCAD BEARING REFURBISHMENT BY ACTIVITY TIMES AND INCREMENTAL CAPITAL COSTS FOR BASIC SUBSYSTEMS

Refurbishement Category by Inspection and Extent of Rework Required	Step	Times (min) Process[2]	Setup[3]	Incremental Capital Costs[1] Item	Cost (198 $)
Restore roundness by grinding	Through dimensional check	10	20		
	Disassemble	1-10		Gages	2,000
	Visual Exam	1		Radius gages	2,000
	Check[5] inner ring	2		Offset gage	500
	Check[5] outer ring	2		Grinder tooling	40,000
	Grind outer ring	8	90		
	Grind inner ring	12	90		
	Magnaflux	2			
	Nitaletch	2			
	Hone Races	10	60		
	Demag and clean	2			
	Sort rolling elements	10			
	Zyglow & check cage	2			
	Reassemble	3-10			
	Clean	1			
	Dimensional Check	3			
	Preserve & package	2			
	Totals	73-89	260		44,500

[5]For concentricity and roundness.

MECHANICAL TECHNOLOGY INCORPORATED

TABLE 7-1 (Cont'd)

CCAD BEARING REFURBISHMENT BY ACTIVITY TIMES AND INCREMENTAL CAPITAL COSTS FOR BASIC SUBSYSTEMS

Refurbishment Category by Inspection and Extent of Rework Required	Step	Times (min)		Incremental Capital Costs[1]	
		Process[2]	Setup[3]	Item	Cost (1980 $)
Handle duplex and triplex sets	For no rework, comes in after recleaning and before final dimensional check. For rework, comes in after race honing.				
	Make partial assembly	1[6]			
	Check set guage	2[6]		Gages and adapters	10,000
	Repair and grind on surface	5[6]			
	Demag and clean	2[7]			
	Reassembly	3[6]			
	Totals	24-35	0		10,000

[6]Per bearing.

[7]Per set.

TABLE 7-2

NONRECURRINC COSTS: BASELINE SYSTEM

	Throughput Capability	Cost ($000)	Total
Diagnostic Subsystem			
Diagnostic Equipment			$ 650K
Diagnostic Test Equipment	10K	500	
Material Handling	3K	150	
Control System			$ 550K
Computer Hardware	5K	350	
Process Software	20K	100	
Equipment Programming	10 sets	100	
Inventory Management			$ 500K
Data Base Managment	5K	250	
Inventory Control Package	5K	250	
Subtotal			$ 1,700K
Refurbishment Subsystem			
Bearing Processing			$ 25K
Disassembly	5K	15	
Handling Duplex/Triplex sets	15K	10	
Honing of Races	3K	150	$ 150 K
Grinding & Replating			$ 505 K
Bore	5K	240	
Outer Diameter	5K	220	
Roundness	5K	45	
Process Documentation	22 sets	400	$ 400 K
Subtotal			$ 1,080 K
Associated Training			$ 350 K
TOTAL			$ 3,130 K

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TABLE 7-3

TIME DATA, BEARING REFURBISHMENT SUBSYSTEM EQUIPMENT CAPABILITIES

(Baseline System)

Restoration Category	Times		Maximum Bearings or Lots/Year	
	Process Time (min./bearing)	Setup Times (min./lot)	If Only Processing is Done[1]	If Only Setups are Do
Race Honing After Disassembly	37-53	60	1956-2802 Bearings	1728 Lots
Grinding and Replating of Bore and OD	83-99	180	1047-1249 Bearings	576 Lots
Restore Roundness by Grinding	63-79	240	1312-1646 Bearings	432 Lots

[1]No Setups

[2]No Processing

TABLE 7-4

NET BASELINE REFURBISHMENT SUBSYSTEM CAPABILITIES

Restoration Category	Maximum Bearings Processed Per Year With Four Setups Per Week Allowed[1]	Percent of Total Rework Flow (8,000/yea That Each Baseline System Can Handle
Race Honing After Disassembly	1752-2510 Bearings/Year	50-72
Grinding and Replating of Bore and OD	730-830 Bearings/Year	21-24
Restore Roundness By Grinding	784-983 Bearings/Year	22-28

[1]Setup times subtracted from total 1,720 hours per year of productive time; processing of bearings is done in remaining time.

7.1.2.1 Diagnostic Subsystem. The recurring cost for the diagnostic subsystem consist of the four elements shown in Table 7-5. The automated system is expected to require less inspection time per bearing than the current system. This saving is not now firmly known, although a rough estimate is that the per bearing inspection time would be approximately 10 minutes per bearing or 70% of the current inspection times. Initially, the bearing flow of 3,500 per year could come from ASTORS, leading to a diagnostic flow of 7,000 per year. At $32 per hour (burdened labor rate), the processing costs would be about $37,000 per year. Maintenance costs are assumed to be as shown and include both labor and material costs. Two man-weeks have been alloted for the annual training above the initial implementation training at the cost of $3,000. Utilities and other miscellaneous costs for the diagnostic subsystem are grouped with the entire system costs and are presented with the refurbishment subsystem costs. The total incremental recurring costs for the diagnostic subsystem are thus $74,000 per year.

7.1.2.2 Refurbishment Subsystem. The recurring costs are dependent primarily on the system throughput. Based on the subsystem process and set-up times summarized in Table 7-6, it appears that 3,500 bearing per year imply roughly 3 man-years of applied labor. These translate to approximately $200,000 per year. (Regarding labor costs, of the 52 week per year, 4 weeks were assumed unavailable because of vacations and holidays. The remaining 48 weeks were further reduced by the assumption that only 90% of this time would be available, the remainder being lost to sick leave and other nonproductive activities. Consequently, only 43 weeks are available for direct labor. Incremental man-year needs are based on these assumptions.)

The utilities and other miscellaneous costs also include spare parts (rolling elements, etc.). These aspects are difficult to estimate accurately. Utilities frequently are relatively low, spare parts costs will vary widely between bearings and may average $10 to $12 per bearing, depending on such factors as the need for individual parts, the availability of salvaged parts at CCAD, and other factors. A figure of $15 per bearing has been used to approximate these other costs. Using this and the other figures given in Table 7-5, the total recurring costs for the baseline system are $352,000 per year.

TABLE 7-5

ESTIMATED RECURRING COST ASSUMPTIONS

BASELINE INSPECTION, DIAGNOSTICS AND REFURBISHMENT

Subsystem/Cost Element	Defining Assumptions	Estimated Incremental Annual Costs (FY 1981 $)	
INSPECTION/DIAGNOSTICS SUBSYSTEM:			
1. Man-hour Costs for Processing and Setup	Automated system may require very roughly 70% of the inspection time of current activities, or about 10 minutes per bearing	$37,000	
2. Maintenance Costs	Assumed to be about 2% of total capital requirements	34,000	
3. Annual Training Costs	Approximated as two man weeks	3,000	
4. Utilities and Other Miscellaneous Costs	Grouped as a lump sum for whole system; shown below under rework subsystem	--	
			$74,000
REFURBISHMENT SYSTEM			
1. Man-hour Costs for Processing and Setup	Three man-years	$200,000	
2. Maintenance Costs	At 20% of capital requirements	22,000	
3. Annual Training Costs	Two man-weeks	3,000	
4. Utilities and Other Miscellaneous, Including Replacement Parts	At $15.00 per bearing	53,000	
			$278,000
	Total System		$352,000

TABLE 7-6

BASELINE REFURBISHMENT SUBSYSTEM PROCESS AND SETUP TIME SUMMARIES

Rework Category	Per-Bearing Process. Time Range (minutes)	Per-Lot Setup Time Range (minutes)
Disassembly	24 - 40	20
Race Honing	36 - 53	80
Bore/O.D. Grinding and Replating	82 - 99	200
Grinding for Roundness Restoration	62 - 79	260
Handling Duplex and Triplex Sets	24 - 35	0

Source: TRW Bearings Division

7.2 Economics System

The economics system differs from the baseline system in that it is configured with enough equipment to support a bearing flow of 8,000 units annually in the refurbishment facility. The choice of this annual flow value warrants some discussion.

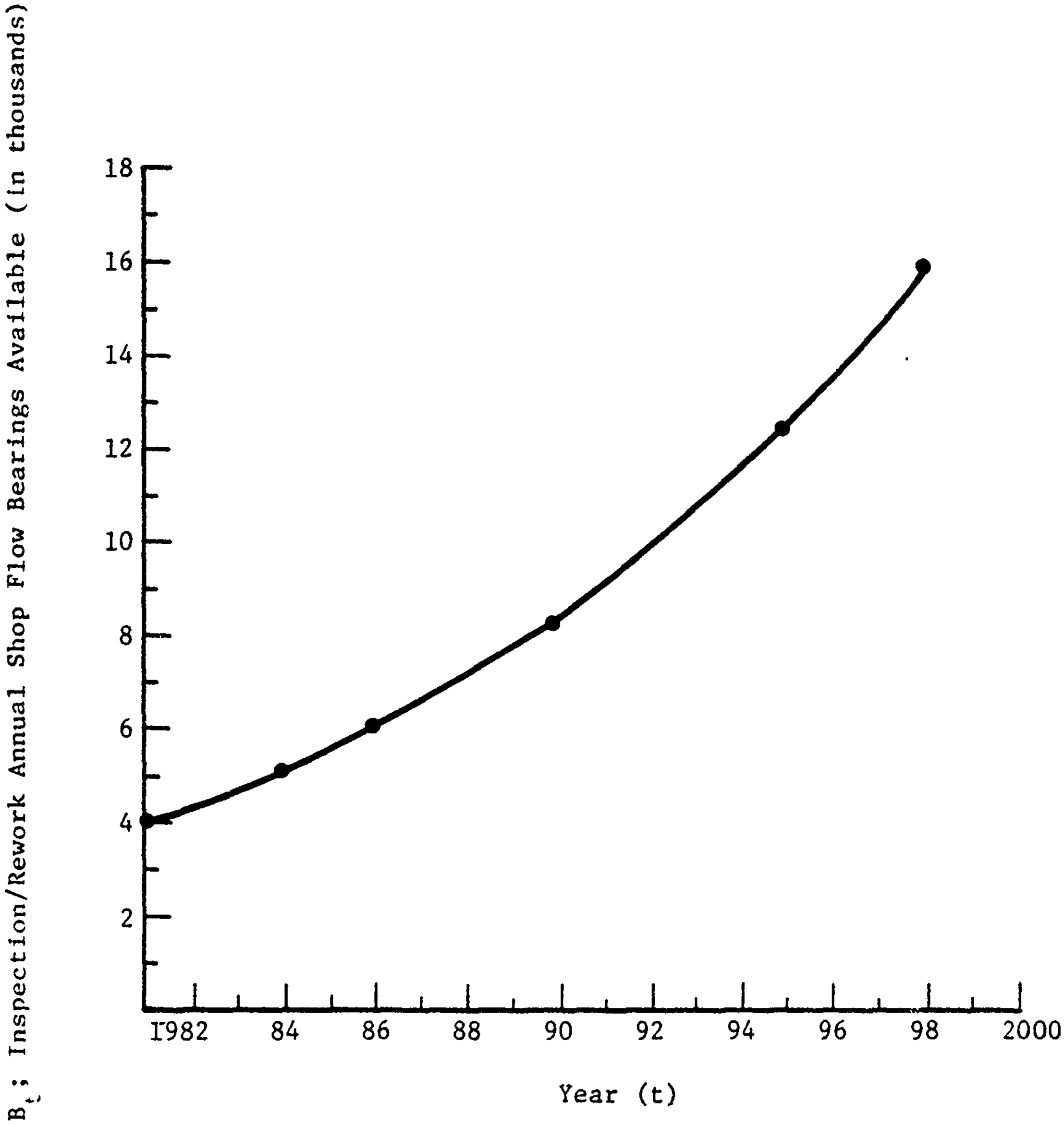
The analysis of the historical records has shown (Table 4-19) that normal operation has included about 4,000 rejected bearings for the critical 22 bearing types in each of the last several years. This potential refurbishment flow of 4,000 bearings per year seems fairly stable over recent history, but the number may increase if Government funding policies shift in the direction of readiness. Figure 7-3 shows what might occur if the flow rate should rise at 8-1/2% annually due to greater activity, new aircraft, or additional engines.

Currently, rejected bearings in these critical categories are being temporarily stored in ASTORS, incrementing it at about 4,000 units per year. The present size of this inventory is reportedly about 14,000 bearings, although some 38,000 bearings have been logged into it. This implies that all 18,000 bearings in these critical categories listed in Table 4-19 may not in fact be there. However, if we assume some lower number and recognize that two years will elapse before contributions to ASTORS can cease, there could be approximately 20,000 bearings in ASTORS to be refurbished when the current system becomes operational. Draining this at 4,000 bearings per year will thus take about 5 years. At this point in time, the compounded growth curve of normal Shop flow (Figure 7-3) will have exceeded some 7,000 per year.

The conclusion drawn from these considerations is that a system configured to process 8,000 bearings per year through the reconditioning subsystem appears to be addressing a very viable opportunity.

7.2.1 Nonrecurring Costs

The cost elements are those described for the baseline system, augmented when necessary to accomplish the higher flows. The results are summarized in Table 7-7.



$B_t = 4000\ (1{,}085)^{t-1981}$

Fig. 7-3 Impact of Hypothetical Increases in Inspection/Rework Bearings Available Due to Increase in Annual Shop Flows (8.5%/year compounded increases assumed)

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TABLE 7-7

NONRECURRING COSTS: ECONOMICS SYSTEM

($000)

	Cost ($000)	Total
Diagnostic Subsystem		
Diagnostic Equipment		750
Diagnostic Test Equipment	500	
Material Handling	250	
Control System		700
Computer Hardware	400	
Process Software	100	
Equipment Programming	200	
Inventory Management		700
Inventory Control Software	300	
Data Base Management	400	
Subtotal		$2,150 K
Refurbishment Subsystems		
Bearing Processing		40
Disassembly	30	
Handling of Duplex/Triplex sets	10	
Honing of Races	450	450
Grinding & Plating		770
Bore	240	
Outer Diameter	440	
Roundness	90	
Process Documentation		400
Subtotal		$1,660 K
Associated Training		$ 450 K
TOTAL		$4,260 K

7.2.1.1 Diagnostic Subsystem. The major change in the inspection equipment arises from the need to provide additional equipment to handle the full set of bearings at this volume level, which may ultimately reach 40,000 bearings per year.

The computer hardware will also require some additional floor stations, communications, and, perhaps, some additional memory modules. The process software must be augmented to control the enhanced material handling equipment and the enlarged reconditioning subsystem. The test equipment programs to guide the testing and diagnosis of the new bearing types must be developed, debugged, validated, and installed.

In inventory management, full data-base management is now required for the 22 bearing types, and components must be enhanced to provide the appropriate treatment for the additional bearing types. The inventory control package will require comparable treatment.

7.2.1.2 Refurbishment Subsystem. Table 7-2 shows that most elements in the refurbishment subsystem need to be replicated once to support the flow; the major exception is the honer, of which three are needed. The numbers reflect another exception, made in the case of the bore grinder. The flexibility and interchangeability of ancillary equipment supplied with the O.D. grinder make it unnecessary to add a second bore grinder, and so those costs have not been included.

7.2.1.3 Associated Training. This amount has been increased to reflect the need to train additional manpower in equipment somewhat more involved than that of the baseline system.

7.2.1.4 Summary. The nonrecurring costs summarized in Table 7-7 show a total costs of $4.26 million for the economics system.

7.2.2 Recurring Costs

The recurring costs for the economics system are approximated in the same manner as with those in the baseline system. They differ only that they

relate to flow rates of 22,000* and 8,000 units per year, respectively, through the diagnostic and refurbishment systems. The values are set forth in Table 7-8.

7.3 Readiness Systems

The readiness system includes the addition of equipment above that in the economics system so that the overall readiness of the bearing facility may be enhanced in the following ways:

- Added system responsiveness by permitting equivalent diagnostic and refurbishment activities for any bearing identified as critical for the overhaul facility
- Increased throughput providing surge capability
- Enhanced process reliability through equipment redundancy
- Improved overall quality of the Shop overhaul operation by identifying present and potential problems in bearings and by permitting their prompt solution.

7.3.1 Nonrecurring Costs

These costs are shown in Table 7-9.

In the diagnostic subsystem, a second diagnostic test stand has been included along with a wider range of adaptors and test fixtures in the material handling area. Provision has also been made for special diagnostic tools and gages to assist with critical bearings.

Modest increases have been made in the control system. Additional floor modules and communication lines are required with, perhaps, further memory expansion. Process control software must be upgraded to accommodate the increased equipment and to provide maintenance diagnostics to assure the desired level of reliability. Algorithms for the rapid generation and validation of inspection and test routines for new bearings must be made available.

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*This is an average, assuming one year where all 8,000 inputs are prescreened (16,000 per year flow) and four where only half are prescreened (implying a 28,000 annual flow).

TABLE 7-8

SUMMARY OF ANNUAL COSTS

($000)

	Baseline	Economic	Readiness
Recurring Costs			
Processing Labor			
Diagnostic	37	128	230
Reburbishment	200	466	685
	237	594	915
Maintenance			
Diagnostic	34	42	63
Refurbishment	22	33	60
	56	75	123
Training, Annual			
	3	6	10
	3	9	15
	6	15	25
Other			
Spare Parts, Utilities	53	120	180
	$352K	$804K	$1243K

TABLE 7-9

NONRECURRING COSTS: READINESS SYSTEM

	Cost ($000)	Total
Diagnostic Subsystem		
Diagnostic Equipment		
Diagnostic Test Equipment	1000	$1500K
Material Handling	400	
Other	100	
Control System		
Computer Hardware	500	$ 950K
Process Software	150	
Equipment Programming	300	
Inventory Management		$ 800K
Inventory Control	350	
Data Base Management	450	
Subtotal		$ 3,250K
Refurbishment Subsystem		
Bearing Processing		$ 80K
Disassembly	60	
Handling of Duplex, Triplex sets	20	
Honing of Races		$ 900K
Grinding & Plating		$1320K
Bore	480	
Outer Diameter	660	
Roundness	180	
Process Documentation		$ 800K
Subtotal		$3,100K
Associated Training		$ 700K
TOTAL		$ 7,050K

The inventory management requires some augmentation. The major addition is in the data-base management area where programs need to be generated to improve quality by identifying present and potential problems in bearings and, perhaps, by application.

The reconditioning subsystem is a more reliable version of the economics system with some quick-response capability to refurbish bearings outside the current process stream.

Added reliability is achieved by including one additional piece of equipment in each category. Quick response follows from added elements in the disassembly and honing categories and an additional grinder (included in the roundness category for computational convenience).

Documentation costs reflect the inclusion of another two dozen bearing types. The associated training is increased because of the enlarged personnel base and the more extensive training likely to be required.

The resulting configuration has an overall throughput capability at least 50% greater than that of the economics system, i.e., approximately 12,000 bearings per year.

7.[illegible].2 Recurring Costs

Recurring costs for the readiness system are difficult to forecast because of the inherent unpredictability in how this resource will be used. To provide some basis of comparison, however, a stand-by mode of operation will be used. Under present circumstances, the added capability of the readiness system could be used to address the next set of bearing types on the prioritized list of critical bearings. For computational convenience, consider the price decomposition shown in Table 7-10. Of the 26,000 bearings in the current Shop flow, the economics system might address only half, leaving the rest for the readiness system. This could provide an added diagnostic flow of 9,000 bearings per year, yielding an additional 4,000 bearings per year at the refurbishment facility. On this basis, subsequent computations will assume 12,000 bearings per year flowing through the refurbishment center and 40,000 bearings per year through the diagnostics center.

TABLE 7-10

ASTORS COUNT BY PRICE (BEARINGS OF UNIT PRICE ≥ $80)

Price Range ($)	FY 1980 Shop Flow Bearings Count	FY 1980 Shop Flow Bearings Replacement Value ($)	Other Bearings Count	Other Bearings Replacement Value ($)	Totals Count	Totals Replacement Value ($)
80-90	3,786	311,085	-0-	-0-	3,786	311,085
91-100	131	12,494	41	3,885	172	16,379
101-120	2,035	212,452	38	4,404	2,073	216,856
121-140	1,206	157,907	15	2,026	1,221	159,128
141-160	5,288	801,748	-0-	-0-	5,288	801,748
161-180	466	82,464	-0-	-0-	466	82,464
181-200	-0-	-0-	-0-	-0-	-0-	-0-
201-220	36	7,615	33	7,029	69	14,644
221-240	1,430	318,890	42	10,080	1,472	328,970
241-260	1,295	334,616	11	2,827	1,306	337,443
261-280	355	966,613	-0-	-0-	355	96,613
281-300	224	63,628	-0-	-0-	224	63,628
301-350	851	286,616	98	30,282	949	316,898
351-400	1,043	389,641	1,121	406,159	2,164	795,800
401-450	-0-	-0-	11	4,411	11	4,411
451-500	4,598	2,172,500	13	5,928	4,611	2,178,428
501-550	-0-	-0-	60	33,000	60	33,000
551-600	568	322,238	113	66,218	681	388,456
601-700	807	501,954	348	232,692	1,155	734,646
701-800	1,141	864,069	-0-	-0-	1,141	864,069
801-900	77	64,680	-0-	-0-	77	64,680
901-1000	399	371,874	-0-	-0-	399	371,874
1001-1500	32	32,896	52	56,576	84	89,472
1501-2000	272	482,528	-0-	-0-	272	482,528
2001 plus	65	132,210	-0-	-0-	65	132,210
TOTAL	26,105	8,890,718	1,996	865,517	28,101	8,885,430

Consequently the recurring costs can be appropriately scaled, and the data are shown in Table 7-8. Scaling has been done as before, and the total annual cost of operations is shown to be $1.243 million per year.

7.4 Savings

There are several economic benefits to be achieved with these systems; however, focus will be placed on only one: the savings associated with replacement costs. Every bearing that is refurbished represents a bearing purchase that does not have to be made.

These replacement savings can easily be described for the economics system. Table 4-19 shows that the annual refurbishment Shop flow of 4,000 bearings has a replacement value of $1.384 million. This table also shows that an ASTORS bearing has an average replacement value of $384, so that the projected replacement value of 4,000 bearings from ASTORS would be $1.536 million. Thus the economic system could provide a potential replacement value of $2.290 million.

The savings for the baseline system would be based on the ASTORS value only. Refurbishing 3,500 bearings annually would lead to an annual replacement value of $1.334 million.

Savings for the readiness system would include those of the economic system, together with those benefits associated with the additional 4,000 bearings being refurbished. To put some estimate on the savings, Table 7-10 was again used to conclude that of the 9,000 bearings considered* each has an average value of $289. This implies a potential additional savings of $1.156 million if 4,000 of these bearings are refurbished annually. As a result, the projected annual savings for the readiness system amounts to $4.076 million.

The various flows and savings are shown in Table 7-11.

*Those bearings outside the ranges $140 to $700.

TABLE 7-11

SUMMARY OF POTENTIAL SAVINGS

	Annual Flow (Refurbishment)	Implied Savings From Reduced Purchase Requirements
Baseline System	3500	$1,344K
Economics System	8000	$2,920K
Readiness System	12000	$4,076K

7.5 Economic Analysis

The costs for the three alternative systems are summarized in Table 7-12, and the economics for the three systems, in Table 7-13.

The baseline system yields net savings of $992,000 each year, providing a net savings of $4.960 million after five years of operation. The system pays back the investment after 38 months of operation.

The economics system yields net annual savings of $2.116 million which total $10.58 million after 5 years. The payback period is 24 months.

The readiness system yields net annual savings of $2.833 million, which totals $14.165 million after 5 years. The payback is 30 months.

It is clear that the economics system is the most attractive. Further evidence comes from a discounted cash flow (DCF) analysis (Table 7-14) which recognizes the monetary value of time. Using 5 years of system implementation and 10 years of operational savings, it indicates that at a 10% discount rate, the investment has a net present worth of $6.2 million. Defining an internal rate of return as that discount rate which brings the net present worth to zero, the table, supplemented by Figure 7-4, shows an IRR of 36%.

Further consideration may be given to inflation, which was omitted from Table 7-1. A mild inflation rate can have significant effects on the net annual savings as is suggested in Table 7-15.

The economics system appears to present a very attractive investment opportunity. A more detailed study to include a system plan in enough detail to confirm the present costing estimate and an analysis of the savings opportunities to support current approximations and quantify some related readiness benefits appears warranted as the first step in the next phase of this program. A planned implementation is suggested in Figure 7-5.

The system to be implemented and the system recommended here is the economics system with some selected options chosen from the readiness system to achieve an appropriately effective mix of economics and readiness.

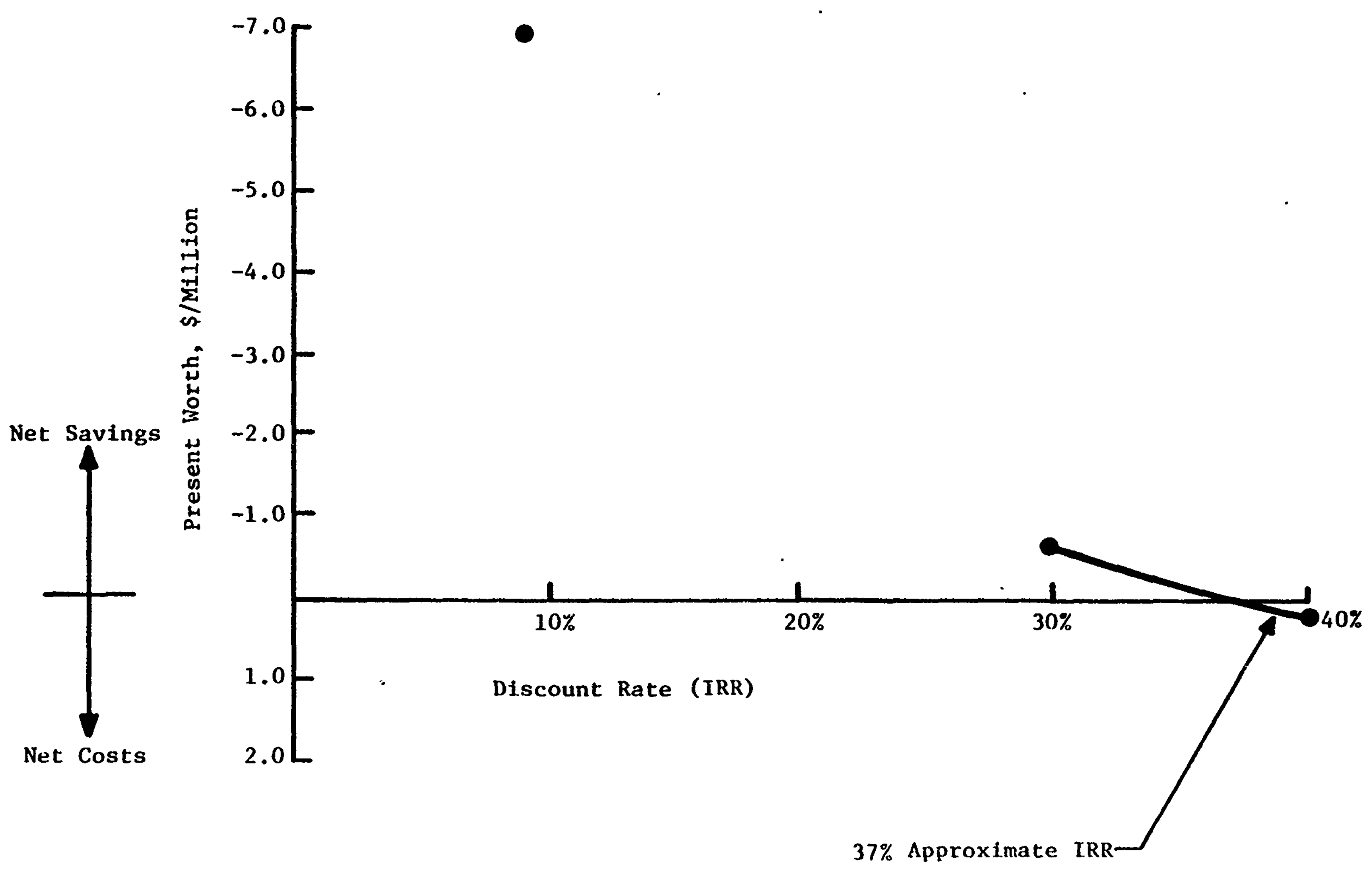

Fig. 7-4 Internal Rate of Return (IRR) Linear Extrapolation Estimate

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TABLE 7-12

SUMMARY OF SYSTEM COSTS

($000)

	Baseline System	Eccnomics System	Readiness System
Non Recurring Cost			
Diagnostic Subsystem	1700	2150	3250
Reburbishment Subsystem	1080	1660	3100
Training	350	450	700
Subtotal Non Recurring	3130	4260	7050
Recurring Costs			
Processing Labor	237	594	915
Maintenance	56	75	123
Annual Training	6	15	25
Other	53	120	180
Subtotal, Recurring	352	804	1,243
Annual Bearing Volume - Refurbishment	3500	8000	12,000
- Diagnostic (II)	7000	28000	48,000

MECHANICAL TECHNOLOGY INCORPORATED

TABLE 7-13

SYSTEM ECONOMICS

($000)*

	Baseline	Economics	Readiness
Annual Data			
- Savings from reduced purchase of replacement bearings.	1,344	2,920	4,076
- Operating expenses	352	804	1,243
Net Annual Savings	992	2,116	2,833
Five Year Savings	4,960	10,580	14,165
Non Recurring Costs	3,130	4,260	7,050
Net Savings at Five Years	1,830	6,320	7,115
Pay Back Period (yrs)	3.16	2.01	2.48

*FY81 $ used.

MECHANICAL TECHNOLOGY INCORPORATED

TABLE 7-14

ANNUAL PROGRAM ECONOMICS

Fiscal Year	System Implementation Costs	Recurring Costs	Savings in Replacement Bearings Purchase	Net Annual Cost (Savings)	Cumulative Costs (Savings)	10% Discount Rate: Discount Factor[2]	10% Discount Rate: Discounted Cash Flow[3]	30% Discount Rate: Discount Factor[2]	30% Discount Rate: Discounted Cash Flow	40% Discount Rate: Discount Factor	40% Discount Rate: Discounted Cash Flow
1981	0.100	-	-	0.100	0.100	1.0000	0.100	1.0000	0.100	1.0000	0.100
1982	1.075	-	-	1.075	1.175	0.9091	0.977	0.7692	0.827	0.7143	0.768
1983	1.075	-	-	1.075	2.250	0.8264	0.888	0.5917	0.636	0.5102	0.548
1984	1.960	-	-	1.960	4.210	0.7513	1.473	0.4552	0.892	0.3644	0.714
1985	0.150	0.804	(2.920)	(1.966)	2.244	0.6830	(1.343)	0.3501	(0.688)	0.2603	(0.512)
1986	-	0.804	(2.920)	(2.116)	0.128	0.6209	(1.314)	0.2693	(0.570)	0.1859	(0.393)
1987	-	0.804	(2.920)	(2.116)	(1.988)[1]	0.5645	(1.194)	0.2072	(0.438)	0.1328	(0.281)
1988	-	0.804	(2.920)	(2.116)	(4.104)	0.5132	(1.086)	0.1594	(0.337)	0.0949	(0.201)
1989	-	0.804	(2.920)	(2.116)	(6.220)	0.4665	(0.987)	0.1226	(0.259)	0.0678	(0.143)
1990	-	0.804	(2.920)	(2.116)	(8.336)	0.4241	(0.897)	0.0943	(0.200)	0.0484	(0.102)
1991	-	0.804	(2.920)	(2.116)	(10.452)	0.3855	(0.816)	0.0725	(0.153)	0.0346	(0.073)
1992	-	0.804	(2.920)	(2.116)	(12.568)	0.3505	(0.742)	0.0558	(0.118)	0.0247	(0.052)
1993	-	0.804	(2.920)	(2.116)	(14.684)	0.3186	(0.674)	0.0429	(0.091)	0.0176	(0.037)
1994	-	0.804	(2.920)	(2.116)	(16.800)	0.2897	(0.613)	0.0330	(0.070)	0.0126	(0.027)
	4.281	8.040	(29.200)	(16.800)			(6.228)		(0.469)		0.309
							Present Worth		Present Worth		Present Worth

[1]Payback comes 25 months after system begins operation.

NOTE: The IRR by linear extrapolation between 30% and 40% is 36%.

TABLE 7-15

EXAMPLE OF INFLATION'S IMPACT ON UNDISCOUNTED ECONOMICS

Fiscal Year	Net Annual Costs (Savings)	Annual Percentage Inflation	Compounded Inflation, 1981 As Base Year	Resulting Inflated Net Annual Costs (Savings)
1981	0.100	-	1.000	0.100
1982	1.072	10%	1.100	1.179
1983	1.072	8%	1.188	1.274
1984	1.887	6%	1.259	1.376
1985	(2.043)	6%	1.335	(2.727)
1986	(2.193)	6%	1.415	(3.103)
1987	(2.193)	6%	1.500	(3.290)
1988	(2.193)	6%	1.590	(3.487)
1989	(2.193)	6%	1.685	(3.695)
	(6.684)			(9.270)

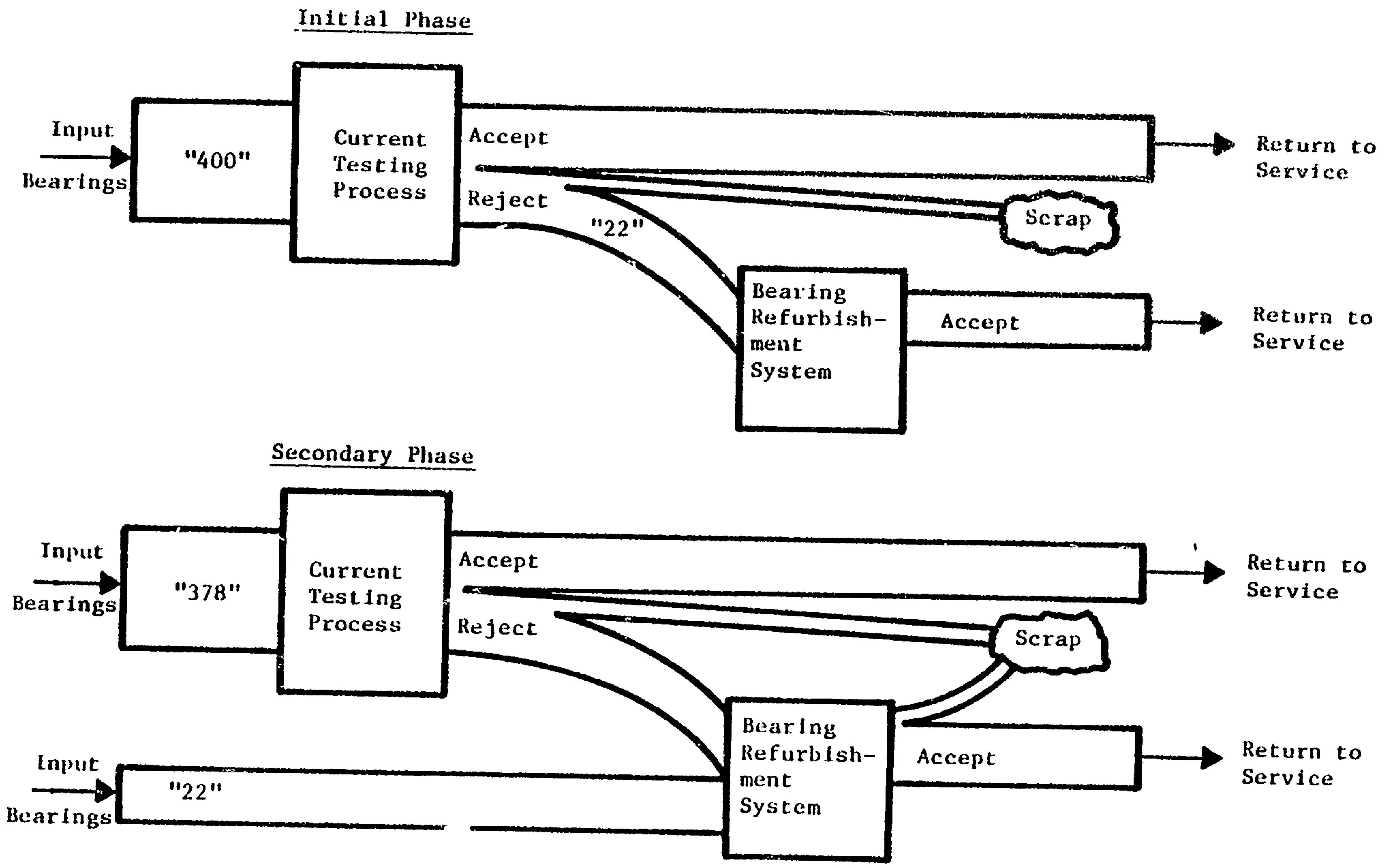

Fig. 7-5 Implementation Phases for Bearing Refurbishment System

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7.6 Summary

The justification for an diagnostic and rework program at CCAD is judged in part on the projected economics. This analysis weights the projected costs to implement and operate a diagnostic/refurbishment program with the savings that would result. These savings are in the form of lower expenditures for procurement of new replacement bearings, and they result from having additional reusable bearings available due to rework.

A segment consisting of 22 of the roughly 400 types of bearings dealt with at CCAD has been selected as candidates for rework. From the annual flow of such bearings through the Bearing Shop and from the number already stored in ASTORS, 8,000 bearings per year are projected for rework from this segment. The Army would save roughly \$2.9 million annually by not having to buy the corresponding number of new replacement bearings.

The costs to make these bearings reusable are the costs to implement the inspection/rework program and the costs to operate and maintain it. A 4-year period (1981-1984) is assumed for program implementation, and a 10-year operational period (1985-1994) is used.

The program does offer the opportunity for reduced cost to the Army through rework of the bearings identified as key candidates. Two ways to look at the economics are presented. For each, the results justify proceeding to further phases of work. It will cost just under \$4.3 million (in FY 1981 dollars) to implement the program by 1985. Annual operations and maintenance costs above this investment are roughly \$0.8 million to rework the 8,000 bearings per year. As the program proceeds through implementation and into operation, funds are spent at specified annual rates (first for program implementation and then for operations). As the operations proceed, savings are realized due to the reworked bearings. Counting dollars of expenditures against dollar of savings, the operations pay back the expenditures after 24 months (in FY 1986). After this point, the program development investment has been amortized, and future-year operations generate net annual savings.

The total annual unit cost to rework the bearings is $207 per bearing. The cost to replace these 5,000 bearings with new bearings would be an average of $[illegible] per bearing. Thus, the ratio of costs to savings is about 0.54, an impressive ratio. Over five years, the program would result in a net savings to the Army of about $6.3 million.

A second approach considers the time value of money in what is called a discounted cash flow analysis. This basically assumes that a dollar today is worth more than a dollar tomorrow, because it could be invested and could return income by tomorrow. Two parameters are of interest in this type of analysis. The Government has, in recent years, viewed investments such as this diagnostic/refurbishment program against a discount rate (annual percentage return that it could obtain by spending its money in another way) of 10% per year. Annual costs and savings are discounted by this rate, and the sum of the annual discounted cash flows is calculated. This present worth provides and indication of how good the program is compared to the investment that would yield 10% per year. For this program and the 14-year period investigated (4 years for implementation and 10 years of operations), the present worth at a 10% discount rate is a net savings of $6.2 million.

In other words, the Army would realize more than 10% per year with the program. How much better is calculated by imposing the requirement that the present worth be zero (no cost or savings) and figuring out the resulting discount rate. When this is done, the program offers a discount rate, or annual percentage return, of 37%.

The economic results are favorable for the program. They are based on reasonably conservative assumptions and should hold up under more intense analysis. They are also only a part of the possible justification for the program, and other factors such as system reliability, equipment readiness, strategic materials use, and other factors should also be considered in making a decision on the program.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations have been reached in the course of the Phase I study performed for the Production Engineering Division of Corpus Christi Army Depot under Contract DAAG48-81-C-004.

8.1 Conclusions

Currently, the CCAD Bearing Shop processes 200,000 bearings annually. These bearings encompass about 400 different part numbers per year and have a replacement value of close to $10 million.

Of the 200,000 bearings processed, approximately 143,000 are from overhauled aircraft and about 57,000 are procured to replace those normally rejected at overhaul. The bearings which are removed from the aircraft at overhaul exhibit a 70% return rate. In other words, 30% of these used bearings are discarded, and the replacement value of the discarded bearings is close to $3 million.

The latest information available on the rework of rejected bearings reveals that 90% of the used bearings could be saved for eventual reuse, leaving only 10% to be discarded. This implies that approximately $2 million could be saved annually (by reprocessing 90% rather than 70% of all the bearings).

Reprocessing the additional 20% of the bearings would require expansion of the CCAD refurbishment activities, combined with some refurbishment activity performed by outside vendors. This is achievable within the present state of the art and within the current space available at CCAD. New equipment, however, must be purchased and additional personnel trained in the diagnosing and refurbishing techniques required to implement bearing refurbishment on a somewhat more complicated scale.

The Phase I study also disclosed that current diagnostic inspection techniques, based on or sight and/or touch by the operator, are difficult if not impossible to standardize. New and proven diagnostic approaches are required to achieve the high degree of reliability called for in the rework of used bearings.

A segmentation analysis of the entire bearing population currently processed through the CCAD shop has disclosed that the expanded refurbishment and diagnostic techniques need not be applied to all bearings to be cost-effective and have a potential savings value to the Government. In fact, only 22 expensive and critical bearings need to be condidered. These 22 bearings can, by themselves, pay for the expansion efforts, including new machinery and personnel training, within a reasonably short time if the reject rate among these bearings, which now hovers between 35% and 50%, is reduced to 10%.

The temporary storage and retrieval system at CCAD also contains about 35,000 bearings, the replacement value of which is approximately $9 million. Here, also, the majority is composed of fairly expensive bearings, and the 22 bearings, previously selected from Shop flow, can, in this case, account for about 85% of the total replacement value.

A preliminary economic analysis, based on the 22 bearings selected as potential rework candidates, indicates that substantial savings can be achieved through the institution of the changes recommended in Section 8.2. The magnitude of these changes depends upon the type of throughput system adopted for implementation. Three different alternatives have been considered, i.e., the "baseline" system, the "economics" system, and the "readiness" system. Each system has been discussed in detail in Section 7.0 of this report.

8.2 Recommendations

Regardless of which of the three alternative economic systems is selected for implementation, particular attention will have to be focused on:

- Implementation of the "economics" system as detailed in this report. At this time, it appears that this system will produce the most benefits in terms of speed of implementation, recurring costs, savings, and payback period.
- Implementation of a more reliable and generally improved bearing inventory management technique. This will permit better control over re-ordering bearings, with particular emphasis on lead time and minimum economic lots.

- Evaluation of all bearing drawings with the objective of arriving at detailed control sheets and specifications for their rework. (Action in this direction has already been taken by NASA-Lewis in Cleveland, Ohio.)

- Review of life limitations currently associated with certain transmission bearings. These life limitations which deal mostly with the fatigue life phenomenon have been imposed by the original aircraft manufacturer and are long due for an additional review. The cost assoicated with the continuation of the existing bearing life limits is particularly apparent in the case of bearing #114-DS-542. Here, a life limit of 1,200 hours which was originally imposed prevented 90% of the bearings from being reused. In FY80, this limit was lifted, and, as a result, all of these bearings were found to be acceptable.

- Further studies to establish the criticality of all the bearings currently processed by CCAD and to rate them accordingly with regard to lead times, minimum order lots, storage life, and rework economy. These studies should provide a clear picture of the impact of each and every bearing on the goals of readiness and economics.

It is finally recommended that, in addition to the actions outlined above, the U.S. Army investigate other sources of supply. (The strong dependence of the Government upon one or two supply sources is showing up in occasional shortages and extremely high jumps in prices over reasonably short periods of time.) The paramount goal should be general readiness. This, again, will involve reduction in lead times, retention of improvement in the quality of the bearings delivered, and, if at all possible, cost reduction.

9.0 REFERENCES

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APPENDIX A

STANDING OPERATING PROCEDURE 700-3-MI
CORPUS CHRISTI ARMY DEPOT

DIRECTORATE FOR MAINTENANCE
CORPUS CHRISTI ARMY DEPOT
Corpus Christi, Texas 78419

STANDING OPERATING PROCEDURE 700-3-M-1

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BEARING PROCESSING REQUIREMENTS

1. Purpose. To establish procedures and responsibility for ordering and processing of bearings.

2. Scope. This SOP is applicable to personnel in the Directorate for Maintenance. Other directorates are referenced for clarity and continuity only.

3. General. a. "Subject Bearings" are all anti-friction "rolling bearings" excluding instrument bearings. Instrument bearings shall be considered to be any bearing used in an instrument. "Rolling bearings" include all metal bearings consisting of ball, needle, or roller element which roll between concentric inner and outer rings.

b. Blank SDSCC Form 104 and 105 can be procured from Blank Forms Storeroom by submitting DA Form 17.

c. To obtain new preprinted part numbered SDSCC Form 105 "Bearing History Data" cards use blank SDSCC Form 105. Enter complete part number placing dashes in correct position in the part number in Col 4 thru 19, shop number of shop utilizing said bearing will be entered in Col 20-24 (Disassembly shop processing bearings to Bearing Shop will use the utilizing shop number in Col 20-24). Enter the National Stock Number (NSN), omitting the dashes, in Col 34-47. Computer will insert dashes in correct sequence in computer printout. Print across face of card "NEW REQUIREMENT," quantity, work center code of requesting shop, stop number, phone extension and name of requester. Example A, Appendix K. Forward to Bearing Shop production controllers who will verify part number and NSN. If not listed on Master List, Bearing Shop production controllers will enter "M" in Col 3 of DIC, A in Col 80 and forward to keypunch, Site G for updating Master List and punching of preprinted cards. New requirement cards reproduced for shops will be blank in card Col 3 of DIC and Col 80. Replenishment of preprinted part numbered SDSCC Form 105 will be obtained by preprinting across face of preprinted card the following: "REPRODUCE," quantity, work center code of requesting shop, stop number, phone extension and name of requester. Example B, Appendix K. Forward card(s) to keypunch, Site G.

4. Responsibilities and Procedures.

a. Bearing Shop Production Control will:

(1) Process bearings and initiate SDSCC Form 105, "Bearing History Data" card, using codes as to action taken in accordance with Appendix I.

*Supersedes SOP 700-3-M-1, dated 23 Feb 1978

NOTE

SDSCC Form 105 will be input to keypunch by 1230 hours on a daily basis. Transactions from 1200 hours the preceding day to 1200 hours on a day of input will be included.

(2) Order bearings for D/Maintenance production shops through respective parts managers from Supply using Program Schedule, Bearing Schedule Report SDSCC Form 104 and Engine Schedule provided by Division Material Branch elements for shop requirements and maintain a 15-day level of Ready for Issue (RFI) bearings above the current scheduled workload. Record action taken IAW Appendix H.

(3) Issue bearings to D/Maintenance work centers accompanied by Shop Traveler and recorded IAW Appendix H.

(4) Bearings on Supply Save List, Supply Letter or causing line stoppage, not having finite operational life per official work requirements will be repaired. Bearings reflected on the Save List, rejected under present criteria will be put in 5-year preservation status and placed in ASTORS as Candidate for Repair (CFR).

(5) Bearings not listed on Save List, Supply Letter will be processed.

(a) Those bearings that we do not have capabilities or material to repair, but cost over $80.00 will be put in a 5-year preservation status and held in ASTORS as Candidates for Repair (CFR).

(b) Bearings costing less than $80.00 that fall out as nonrepairable or no material available to repair will be scrapped. (See Appendixes D and E).

(6) Exception to paragraph 4a(5) may be directed by a Joint Production Engineering and TSARCOM Engineering decision on a Production Engineering Memorandum and attached to this SOP in the Bearing Shop. All changes will be discussed with Production Control elements in the Bearing Shop.

(7) Bearings being scrapped will have the silver parts removed, weighed, tagged, boxed (identify box as to contents of precious metals) and send to PDO.

(8) Upon receipt of bearings from D/Maintenance shops with Bearing History Data Cards (SDSCC Form 105), verify quantities and Part Number, record additional action taken IAW Appendix H and submit to keypunch.

(9) When mistakes in identification or quantity of bearings are detected, the Production Controller in the Bearing Shop will notify the applicable Materiel Branch Section Chief immediately.

(10) Initiate SDSCC Form 105 on bearings received from sources other than D/Maintenance. (See Appendix B).

(11) CFR bearings will be processed to ASTORS on SDSCC Form 105 IAW SOP 700-98-M-1, enter part number in Columns 8 thru 20 in Block 9 and bearing re-

ject code in Columns 22 and 23. The following entries will be made on SDSCC Form 105 when processing bearings to CFR storage. Enter code letter "c" in Col 3 of DIC, part number in Col 4-19, "p" in Col 26 of RCVD CD, Julian Date bearings are received in CFR in Col 27-30, total quantity of bearings in Col 31-34 being placed in CFR for a given day, "A" in Col 80 of CCD. Enter quantity under reject code Col 36-71, ship code "T" in Col 36, Julian date shipped to CFR in Col 42-45, total quantity shipped to CFR on a given day. When bearing are received from CFR for future processing, SDSCC Form 105 will have the following entries: U in Col 3 of DIC, part number in Col 4-19, work center code in Col 20-24, T in Col 26 of RCV^r, date bearings received in Col 27-30, A in Col 80 and quantity received f a given reject in Cols 36 thru 71. The total of Col 36 thru 71 will equal the quantity in Col 27-30. This transaction card will input to used bearing data and remove from CFR data listing.

(12) Receive and maintain on file for 60-days the following D/MIS computer listing, "Bearing History Status," RIN MØ2RJ3Ø4Ø4D, the list and last of the month. (See Appendix J).

(13) Receive and maintain on file for one year the following D/MIS computer listing, "Completed Bearing History Status", RIN MØ2RJ3Ø4ØM.

(14) Receive punched SDSCC Form 105 from keypunch and maintain in file one calendar month.

(15) Receive other depot's Bearing History and Shipment Data. Place one copy of report and one copy of reject codes identifying cause of rejects with bearing being returned to customer.

b. Bearing Shop will:

(1) Accomplish Ready for Issue (RFI) inspection in accordance with TM 55-1500-322-24 and TED on all new subject bearings except those having non-removeable metal shields.

(2) Process used bearings in accordance with TM55-1500-322-24 and TED's.

(3) When a nonrepairable defect which results in rejection is found in a bearing, the other parts will be given a quick inspection (approximately one-minute) to determine if there are any other recognizable defects.

(4) A normal amount of time will not be spent searching for defects in the cage or races unless the rolling elements are to be replaced during the present tour in the Bearing Shop.

(5) Bearing Shop Production employees will identify bearings as to cause or rejection and record on SDSCC Form 105 IAW Appendix I. Employees will place SDSCC Form 105, "Bearing History Data" with Shop Traveler and bearings placed in baskets identified as to the cause of rejection.

(6) Repackage all subject bearings. The Bearing Shop supervisor or his representative will stamp each bearing package. The part number, serial number and time if applicable will be indicated on the package. Additionally, new bearings shall have "NEW" stamped on the package.

c. Applicable Work Center Production Controllers will:

(1) Provide Bearing Shop Production Controllers with Program Schedule and a projected 2-week bearing usage schedule, 4 workdays prior to date required. (See Appendix F and G). Engines will continue to Supply only engine schedule. Bonafied emergency request may be made by phone to the Bearing Shop production controllers.

(2) New bearings will not be ordered from Supply by work center production controllers but by Bearing Shop production controllers in accordance with program schedule provided Program Managers.

(3) All removed bearings will be routed to the Bearing Shop except those with an acquisition cost of less than $25.00 that are obvious rejects. Exception to the above may be prescribed by TED, Save List or Production Engineering Memorandum. The Bearing Shop is the only shop authorized to dispose of rolling bearings with an acquisition cost of $25.00 or more.

(4) Process bearings to the bearing shop. Like-part number bearings will be processed on one Shop Traveler unless historical data, operating hours or end item requires same bearing be installed.

(5) Prepare two SDSCC Form 105 "Bearing History Data" cards for each batch of like-part numbered bearing being processed for any one given day.

NOTE

If there are more than one container of like-part number bearings, one card will be made for each container and one card for the total quantity of like-part number bearings.

(a) Make one card and place with each container indicating quantity of bearings in container. Make another card or total card and have an "A" placed in column 80 to indicate initial Add card to computer. The "A" cards will be all placed in one packet or envelope and sent to the Bearing Shop with the Bearings being processed. Mark packet or envelope with an "A". Do not place the "A" cards in distribution boxes for pick up.

(b) Make the following entries on SDSCC Form 105, Col 30 of DIC, Col 4-19, 20-24 if cards are not preprinted with part number and work center code. Col 26 of RCVD CD, Col 27-30 of Date RCVD (Julian Date bearings are delivered to Bearing Shop), Col 31-34, QTY RCVD Col 80 of CCD will have an "A" placed on the total quantity card indicating the initial Add card. (See Appendix A and I).

(c) Insure that part numbers and quantity in containers, listed on the Shop Traveler and SDSCC Form 105 correspond.

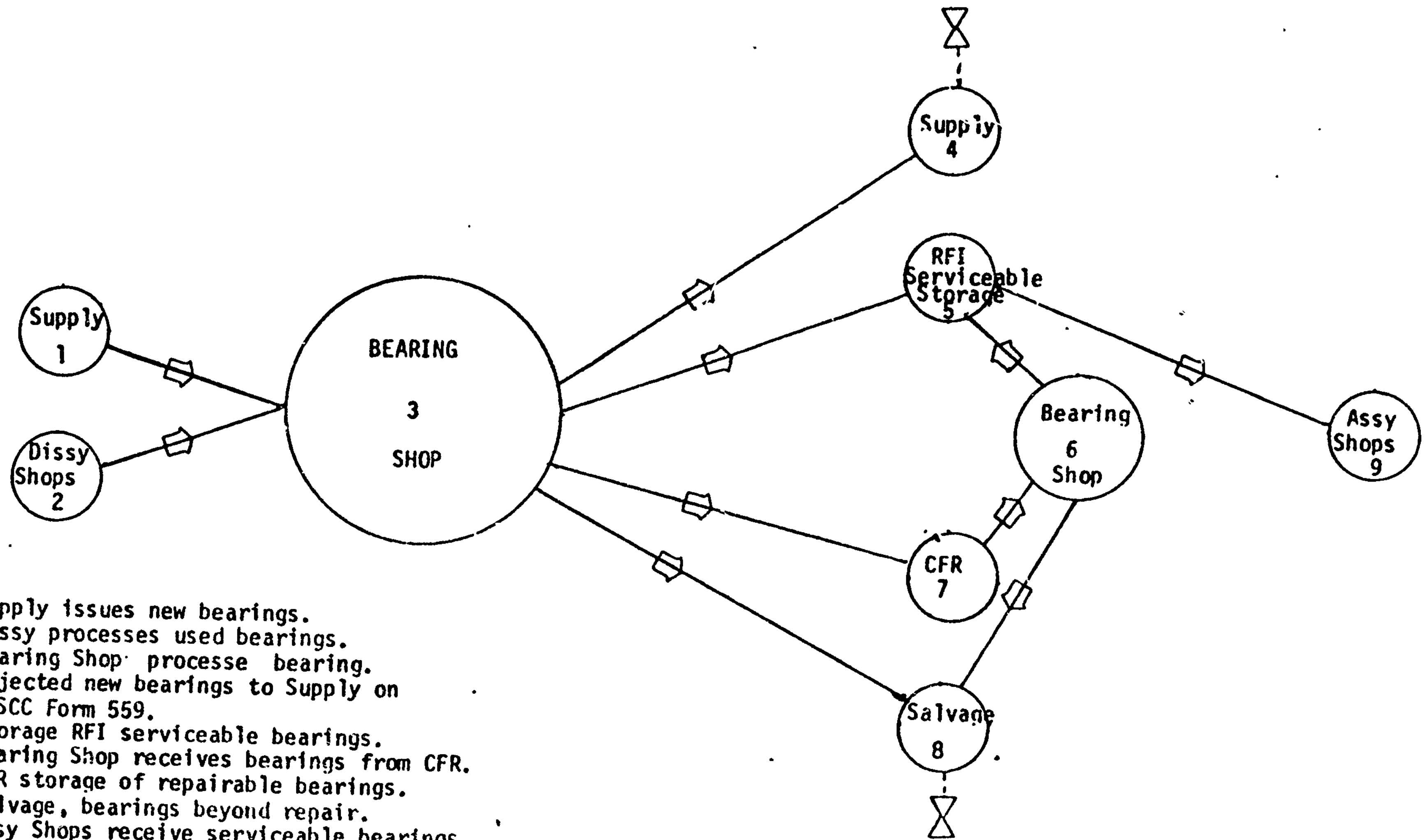
(d) Person preparing SDSCC Form 105 will initial upper right corner.

(e) Production Shop Supervisors will assure that bearing package is not opened until time of installation.

(f) Materiel Branch Section Chiefs will assure that corrective action is taken no later than 1-day after notification of errors on SDSCC Form 105 are received.

APPENDIX A

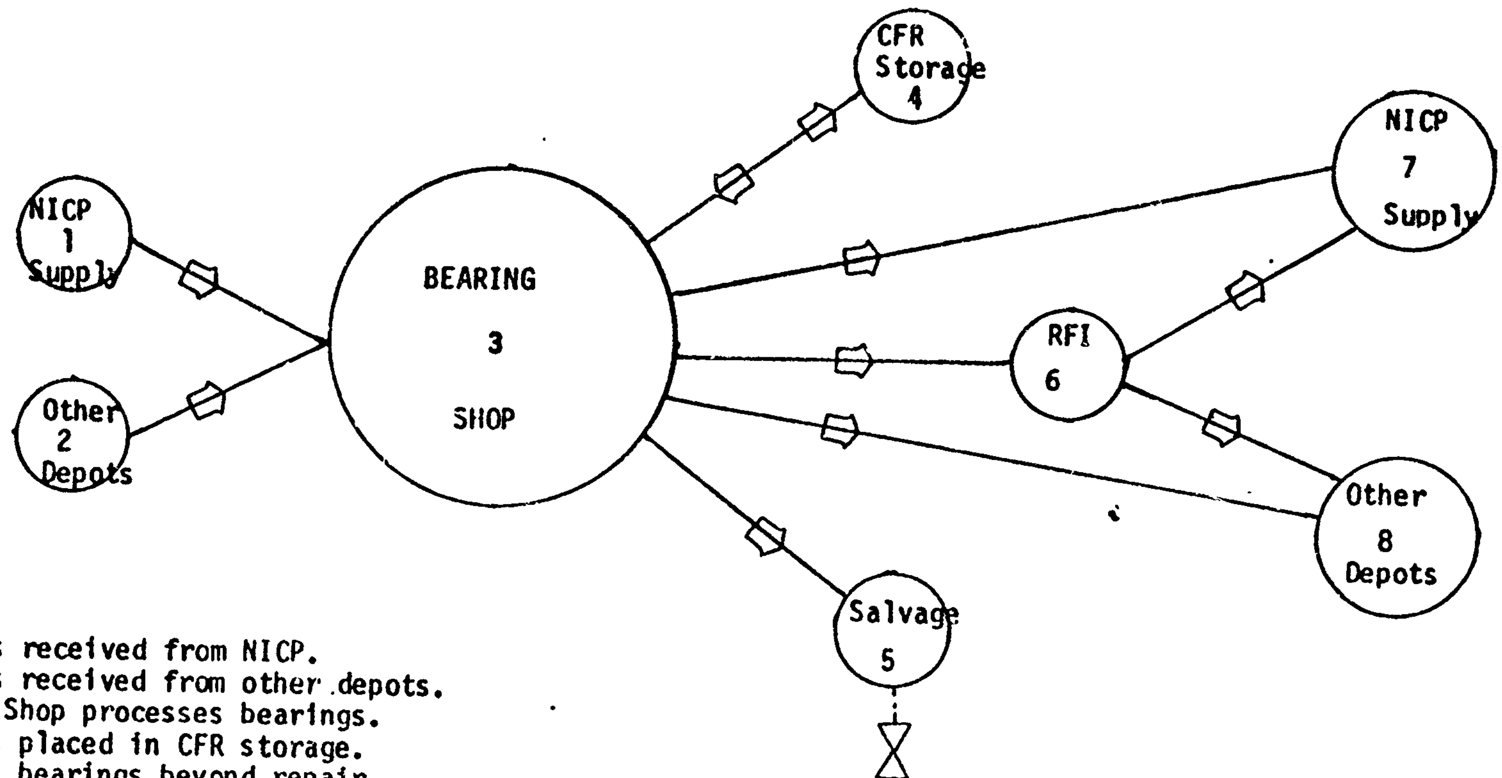
IN-HOUSE BEARING FLOW CHART



1. Supply issues new bearings.
2. Dissy processes used bearings.
3. Bearing Shop processe bearing.
4. Rejected new bearings to Supply on SDSCC Form 559.
5. Storage RFI serviceable bearings.
6. Bearing Shop receives bearings from CFR.
7. CFR storage of repairable bearings.
8. Salvage, bearings beyond repair.
9. Assy Shops receive serviceable bearings.

APPENDIX B

OTHER DEPOTS AND SUPPLY NICP BEARING FLOW CHART

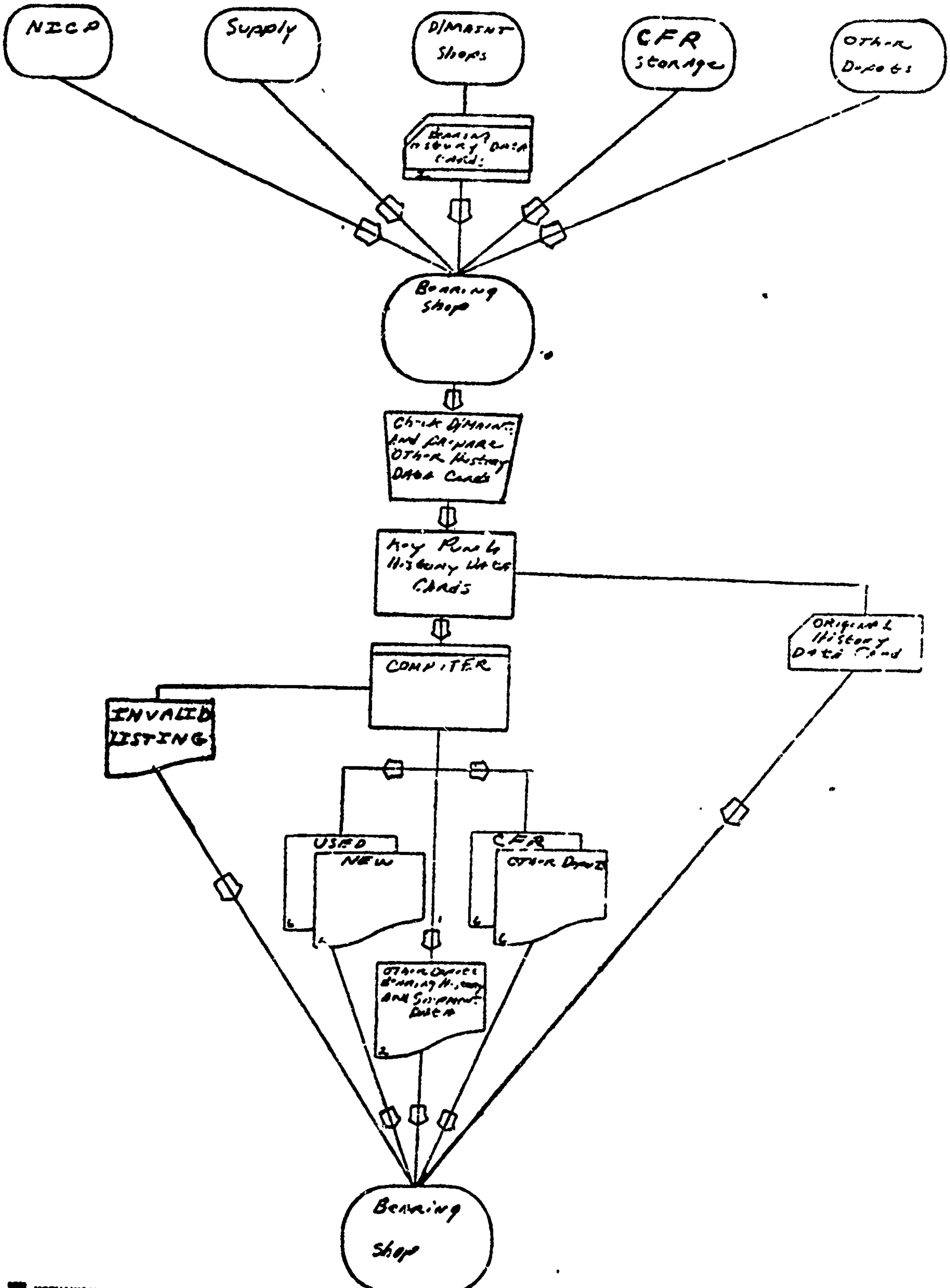


1. Bearings received from NICP.
2. Bearings received from other depots.
3. Bearing Shop processes bearings.
4. Bearings placed in CFR storage.
5. Salvage, bearings beyond repair.
6. Storage, RFI serviceable bearings.
7. Supply NICP receives serviceable bearings.
8. Other depots receives serviceable bearings.

APPENDIX C

2 3 FEB 1978

BEARING FLOW CHART



MECHANICAL TECHNOLOGY INCORPORATED

APPENDIX D

23 FEB 1978

PROCEDURE FLOW PROCESS CHART	Operation	Review	File	Movement	Info	Destroy

Subject of Process: New Bearing Procedures

Action	Concerned Elements						
	Com-puter	Supply	Bear-ing Shop	Serv Stor-age	CFR	Assy Shop	Sal-vage

1. Supply issues new bearing to Bearing Shop.

2. New bearings received by Bearing Shop & SDSCC Form 105, input to computer.

3. New bearing processed by Bearing Shop.

4. New bearings found unserviceable will be re-turned to Supply on SDSCC Form 559 for credit & action recorded on SDSCC Form 105 for input to computer.

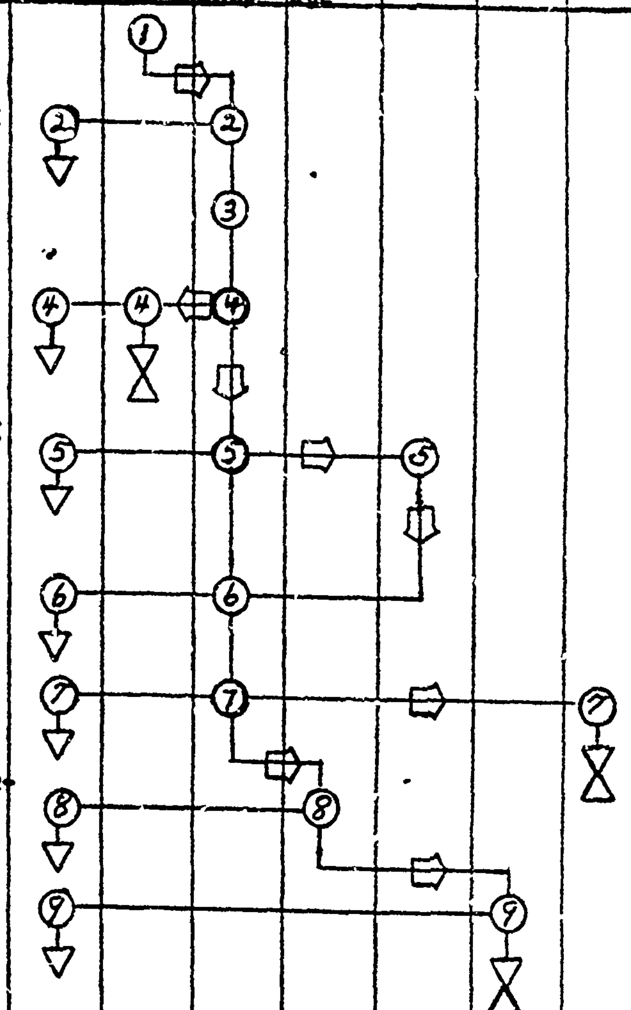
5. Repairable new bearing not submitted on SDSCC 559 to Supply & with an acquisition cost of $80.00 will be placed in CFR storage and recorded on Form 105 to input to computer.

6. Bearings withdrawn from CFR for repair. Ac-tion reported on SDSCC Form 105.

7. Bearings beyond repair processed to salvage and action recorded on SDSCC Form 105.

8. Serviceable bearings to RFI storage action re-ported on SDSCC Form 105.

9. Bearings issued to assembly shops from RFI storage. Action reported on SDSCC Form 105.



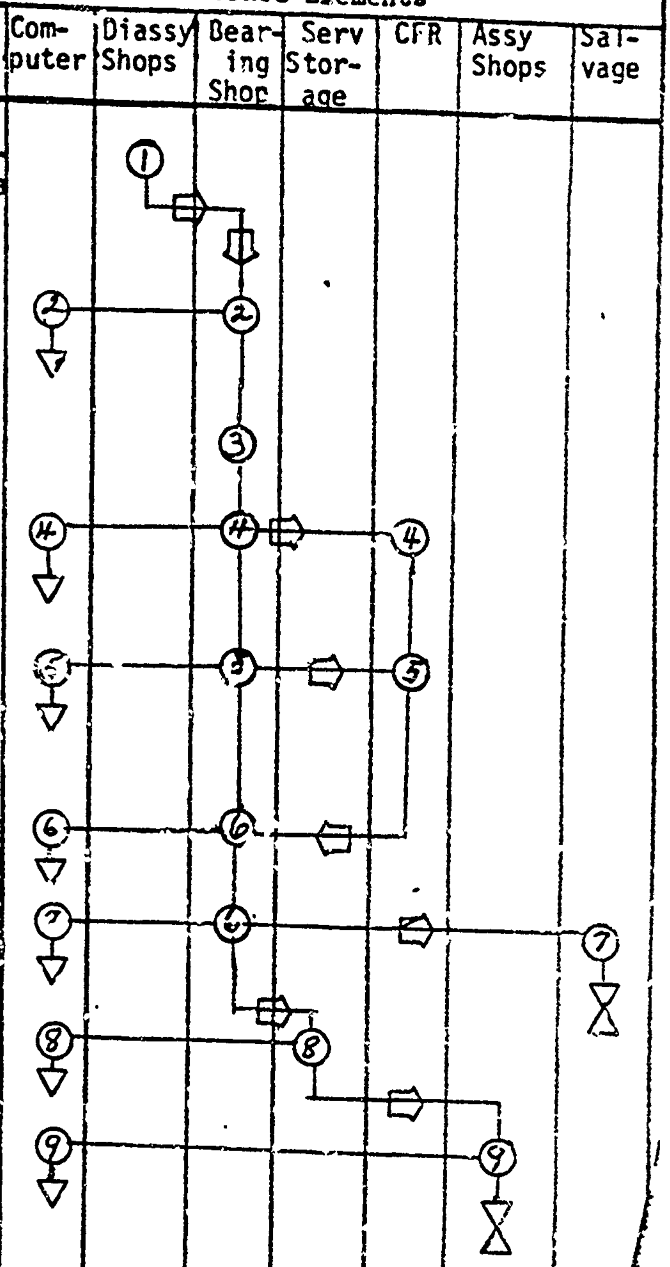
23 FEB 1978

PROCEDURE FLOW PROCESS CHART

Operation | Review | File | Movement | Info | Destroy

Subject of Process: In-house Used Bearing Procedures

Action — **Concerned Elements**



1. Disassembly shops send used bearings to Bearing Shop with Traveler and 2 Bearing History Data Cards, SDSCC Form 105.

2. Bearing received by Bearing Shop, SDSCC 105 card checked for quantity and dated. One card input to computer to update awaiting process. One card remains with Traveler.

3. Used bearings processed by Bearing Shop and repaired if possible.

4. Bearings on Save List that are unrepairable on initial processing will be routed to CFR and action input to computer on SDSCC Form 105.

5. Bearings not on Save List that are unrepairable on initial processing and with an acquisition cost of $80.00 or more will be placed in CFR storage and action input to computer

6. Bearings withdrawn from CFR for repair. Action input to computer on SDSCC Form 105.

7. Bearings beyond repair processed to salvage and action input to computer.

8. Serviceable bearings to RFI storage. Action input to computer.

9. Bearing issued to assembly shops from RFI serviceable storage and action recorded on SDSCC Form 105 and input to computer.

SDSCC Form 736, 20 Oct 67

APPENDIX F

INSTRUCTIONS FOR PREPARING SDSCC FORM 104
BEARING SCHEDULE REPORT

All applicable blocks will be completed to reflect accurate data as it relates to each weeks work schedule.

1.	DATE	Date report submitted.
2.	PAGE___of___	Number of pages in report.
3.	SHOP	Shop No. submitting report.
4.	PRODUCTION CONTROLLER	Name of Production Controller submitting report.
5.	NSN	National Stock Number. Slash numeric Ø.
6.	P/N	Part Number. Slash numeric Ø.
7.	PCN	Job Order Production Control No.
8.	UNIT OF ISSUE	Type of issue (EA, Set, etc.).
9.	BEARING REQUIREMENTS 1ST WEEK	Bearings required for next weeks scheduled production.
	2ND WEEK	Bearings required for the following weeks production.
10.	BEARINGS ORDERED QTY	Bearing Shop enters quantity they do not have available for 2-week schedule and have ordered from Supply.
11.	REMARKS	Self-explanatory.

APPENDIX G

1. DATE: 4 MAY 77

BEARING SCHEDULE REPORT

2. Page 1 of 1

3. SHOP 5EBIB

BEARING REQUIREMENTS (2 Weeks)

4. J. DOE
Production Controller

5	6	7	8	9		10	11
NSN	P/N	PCN	UNIT OF ISSUE	BEARING REQUIREMENTS 1st week Thru 5/13/77	2nd week Thru 5/20/77	BEARINGS ORDERED (QTY)	REMARKS
3110-00-691-2157	204-040-135-1	X08EQG	EA	15	25	30	
3110-00-625-0114	204-040-143-1	X08EQG	Pr	15	25		
3110-00-731-7977	204-011-412-1	X04ENC	SE	15	25	5	
3110-00-836-0443	114DS249-1	X04EW8	EA	8	6	2	URGENT

Sample

DRXAD Form 104, 30 Jun 77

APPENDIX H

Instructions for Preparing SDSCC Form 105, Bearing History Data

COLUMN	TITLE	EXPLANATION
1-3	DIC	Type(s) of bearings.
4-19	PN	Part Number of bearing(s): Slash numeric Ø. (Part number will be at top of card on preprinted cards).
20-24	WK Center	Work Center Code of shop utilizing said bearing(s). On preprinted cards, shop code will be in upper right corner.
25-26	RCVD CD	Bearing source code (Received From) listed in Appendix I.
27-30	DATE RCVD	Julian Date bearings received by Bearing Shop.
31-34	QTY RCVD	Quantity of bearings received the same day and Col 1 thru 26 are identical.
35-47	NSN	National Stock Number will be entered only when a new requirement is placed for preprinted cards on bearings that have not been previously processed.
80	CCD	Enter "A" for initial receipt transaction, "D" to delete and one (1) to correct (overlay).
36-71	REJECTS	Enter quantity of bearings in coded block rejected for defects listed in Appendix I.
72-75	RFI	Enter quantity of bearings processed and serviceable Ready for Issue (RFI).
35-36	SHP CD	Enter Bearing Shipped to Code when shipping bearing. Codes listed in Appendix I.
37-41	WORK CTR	Enter Work Center Code only when shipping bearing to work center other than one listed in Col 20-24 above or in upper right corner of preprinted card.
42-45	DT SHPD	Enter Julian Date, bearings shipped.
46-49	QTY SHPD	Enter quantity of bearings shipped.
50-51	SHP CD	Enter Bearing Shipped Code when shipping bearings.
52-56	Work CTR	Enter Work Center Code when shipping bearings to work center other than one listed in Col 20-24 or in upper right corner of preprinted card.
57-60	DT SHPD	Julian Date bearings shipped.
61-64	QTY SHPD	Quantity of bearings being shipped to work center.
65-79	QTY SHPD	Additional shipping block.

21 JUN 1978

204-011-112-1 SLB3P

DIC	PART NUMBER	WORK CENTER	RCVD CD	DATE RCVD	QTY RCVD	N S N	CC
BGU			RP	7157	15Ø		A

	AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS	UK	REI
U	4	1		1Ø						1Ø			1ØØ

SHP CD	WORK CTR	DT SHPD	QTY SHPD	SHP CD	WORK CTR	DT SHPD	QTY SHPD	SHP CD	WORK CTR	DT SHPD	QTY SHPD
SP		7167	25	SP	5E83C	7187	25	S			

SOSCS FORM 105 BEARING HISTORY DATA

TYPE/S OF BEARINGS	DIC
B = USED-REWORK	BGB
C = CANDIDATE FOR REPAIR	BGC
N = NEW	BGN
U = USED	BGU

BEARING REJECT CODES

AA = RACE

AB = RACE & ROLLING ELEMENT

AC = RACE & CAGE

BB = ROLLING ELEMENT

BC = ROLLING ELEMENT & CAGE

CC = CAGE

DD = RACE/ROLLING ELEMENT/CAGE

LL = FINITE

OO = OBSOLETE

OT = OUT-OF-TOLERANCE

SS = SALVAGE/SCRAP

UK = UNKNOWN

APPENDIX I (Continued)

BEARING SOURCES (RECEIVED FROM & SHIPPED TO):	RECEIVE CODES	SHIP CODES
OTHER DEPOTS:		
US ARMY TANK-AUTOMOTIVE COMD	RA	SA
US ARMY ARMAMENT COMD	RB	SB
US ARMY ELECTRONICS COMD	RC	SC
USA TROOP SUPPORT & AVIATION MATERIEL READINESS COMD	RD	SD
US ARMY MISSILE COMD	RE	SE
USA AVIATION RESEARCH & DEVELOPMENT COMD	RF	SF
ANNISTON ARMY DEPOT	RG	SG
LETTERKENNY ARMY DEPOT	RH	SH
NEW CUMBERLAND ARMY DEPOT	RJ	SJ
RED RIVER ARMY DEPOT	RK	SK
SACRAMENTO ARMY DEPOT	RL	SL
TOOELE ARMY DEPOT	RM	SM
TOBYHANNA ARMY DEPOT	RN	SN
MAINTENANCE	RP	SP
SUPPLY	RR	SR
N.I.C.P.	RS	SS
CFR STORAGE	RT	ST

APPENDIX I (Continued)

Definitions

TYPES OF BEARINGS

B = Used Rework	Used bearings that have been processed by Bearing Shop and issued to D/Maint shops as serviceable, but have not been used or storage date has expired.
C = Candidate for Repair	Bearings that have been rejected but can be repaired or have good component parts that can be utilized for cannibalization.
N = New	New bearings received from Supply that have not been previously issued by the Bearing Shop to D/Maint Shops. Use Receive Code R in Rec'd CD column 29. New bearings that are serviceable but are not needed or the storage date has expired, use Received Code P in Rec'd CD column 29.
U = Used	Bearings removed from components and sent to the Bearing Shop for repair.

APPENDIX J

M02RJ304040 B E A R I N G H I S T O R Y S T A T U S AS OF 03/16/78 PAGE 11

5EB1B

PART NO: 204-040-271-3 NSN: 3110-00-781-9880

SRC	TP	RCV DT	QTY	RFI	APROC	REJ TOT	REJ PCT	REJ/CODE AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS	SHPD TO	SHP QTY	SHP DT
P	U	7338	56	0	46	2	3.5						2						5EB1B	8	8046
P	U	8009	22	0	22	0	0.0														
P	U	8018	25	0	25	0	0.0														
P	U	8028	48	0	28	2	5.0				2								5EB1B	18	8066
P	U	8035	9	0	9	0	0.0														
P	U	8045	28	0	28	0	0.0														
P	U	8049	14	0	14	0	0.0														
P	U	8056	16	0	16	0	0.0														

P/N TOTALS:	RCVD	RFI	APROC	REJCT	SHPD	AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS
	232	0	172	4	26				2		2					

PART NO: 204-040-319-1 NSN: 3110-00-822-2130

SRC	TP	RCV DT	QTY	RFI	APROC	REJ TOT	REJ PCT	REJ/CODE AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS	SHPD TO	SHP QTY	SHP DT
P	N	4055	16	0	16	0	0.0														
P	U	8045	96	0	74	14	14.5	14											5EB1B	8	8061
P	U	8049	145	0	145	0	0.0														
P	U	8056	32	0	32	0	0.0														

P/N TOTALS:	RCVD	RFI	APROC	REJCT	SHPD	AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS
	291	0	269	14	8	14										

PART NO: 205-040-242-1 NSN: 3110-00-199-7398

SRC	TP	RCV DT	QTY	RFI	APROC	REJ TOT	REJ PCT	REJ/CODE AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS	SHPD TO	SHP QTY	SHP DT
P	U	7351	34	0	34	0	0.0														
P	U	8026	80	0	80	0	0.0														
P	U	8028	56	0	56	0	0.0														
P	U	8037	18	0	18	0	0.0														
P	U	8056	24	0	24	0	0.0														

P/N TOTALS:	RCVD	RFI	APROC	REJCT	SHPD	AA	AB	AC	BB	BC	CC	DD	LL	OO	OT	SS
	212	0	212	0	0											

5EB1B	Work Center Code.
PART NO	Part Number.
NSN	National Stock Number.
SRC	Source bearings received from, See Appendix I.
TP	Type of bearing being processed. See Appendix I.
RCV DT	Julian date bearings received by Bearing Shop.
QTY	Quantity of bearings received by Bearing Shop.
RFI	Quantity of serviceable bearings Ready for Issue (RFI) in Bearing Shop.
APROC	Quantity of bearings waiting to be processed by Bearing Shop.
REJ TOT	Total number of rejected bearings.
REJ PCT	Percentage of rejected bearings in relation to quantity received.
REJ/CODE	See Appendix I "Bearing Reject Codes".
SHPD TO	Work center or Shipped to Code. See Appendix I.
SHP QTY	Quantity of bearings shipped.
SHP DT	Julian date bearings shipped.
P/N TOTALS	Summary total for a given part number, shop, D/Maint, Supply (new bearings) and grand totals.

2 - JUN 1978

EXAMPLE A

SAMPLE

DIC | PART NUMBER | WORK CENTER | RCVD CD | DATE RCVD | QTY RCVD | N S N

BG1 2-3ØØ-Ø23-1 5CC3F R 311ØØØ8776163

NEW REQUIREMENT

5Ø EA WC 5CC3F STOP25

EXT 3679 J. Doe.

SHP CD | WORK CTR | DT SHPD | QTY SHPD

S S S

SDSCC FORM 105 BEARING HISTORY DATA

EXAMPLE B

2-300-023-1 SAMPLE 5CC3F

DIC | PART NUMBER | WORK CENTER | RCVD CD | DATE RCVD | QTY RCVD | N S N

BG1 R

REPRODUCE

1ØØ EA WC 5CC3F STOP25

EXT 3679 J. Doe.

SHP CD | WORK CTR | DT SHPD | QTY SHPD

S S S

SDSCC FORM 105 BEARING HISTORY DATA

MECHANICAL TECHNOLOGY INCORPORATED

(SDSCC-MSP)

ROBERT E. AINSLIE
Colonel, TC
Director for Maintenance

DISTRIBUTION:
E

APPENDIX B

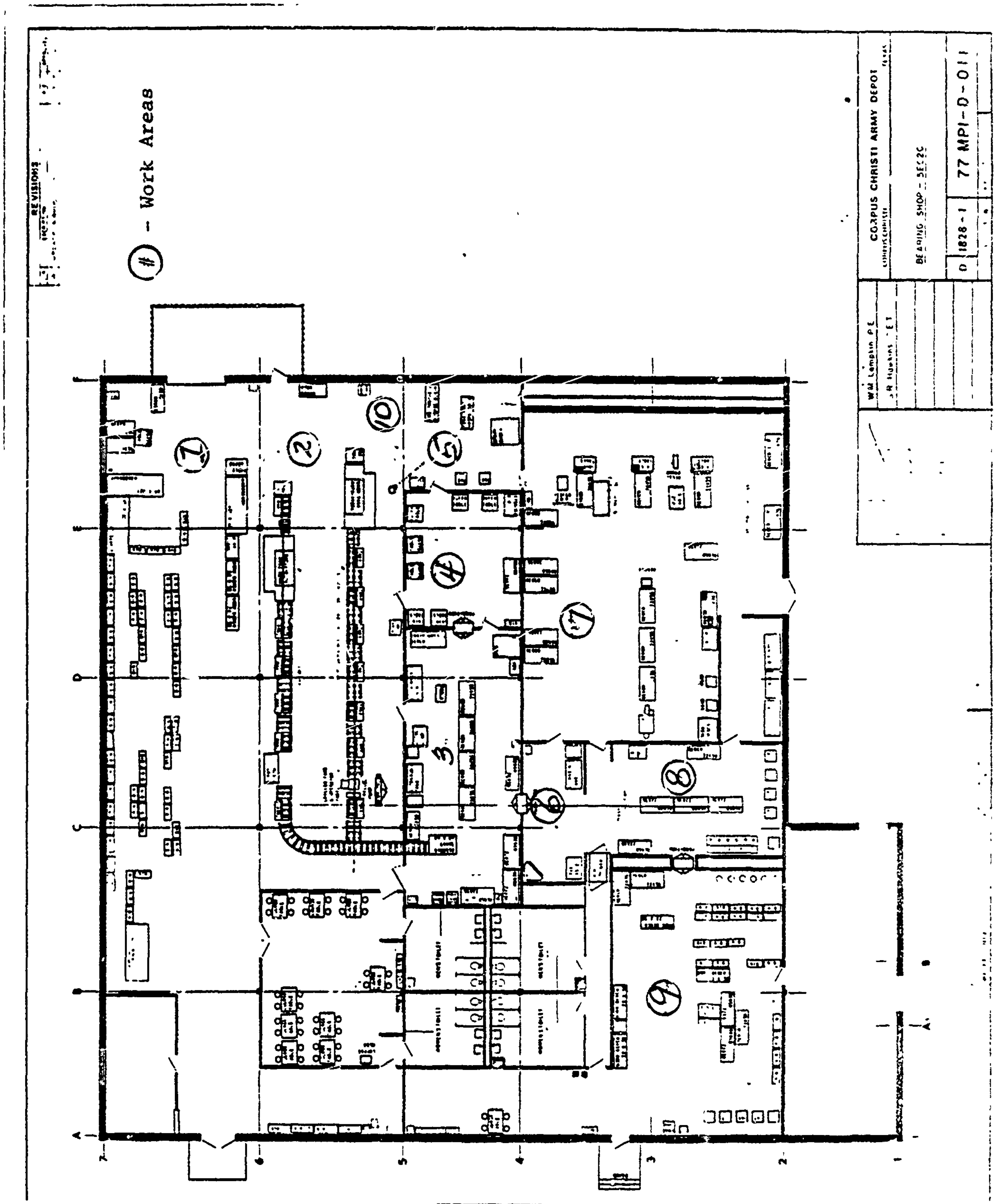
MECHANICS OF BEARING FLOW AT CCAD SHOP
(Includes List of Existing Equipment)

The CCAD Bearing Shop

The current CCAD Bearing Shop facilities will be discussed in detail in this appendix. For purposes of this discussion, the Shop has been segmented into 10 work areas as follows:

- Induction and Prescreening
- Cleaning
- Initial Examination
- Buffing/Polishing
- NDT
- Final Clean
- Dimensional Check/Inspect
- Preservation/Lubrication/Temporary Cover
- Packaging/Packing/with Storage
- Scrap.

CCAD Drawing #77 MPI-D011, Bearing Shop - 5E C2C, has been numbered to show the physical location of the 10 work areas within the Shop.



- Work Areas
REVISIONS
CORPUS CHRISTI ARMY DEPOT
77 MPI-D-011
1828-1

Work Area #1 - Induction and Prescreening

The major Shop workload includes bearings removed from aeronautical equipment during overhaul and/or rework. Bearings are inducted into the Bearing Shop in Work Area #1. The bearings are received directly from the various disassembly shops and are in protective plastic wrap or suitable covered containers. These bearings are generally needed for the immediate support of current production schedules. New bearings are also routed to the Bearing Shop for inspection.

The primary functions of the induction and prescreening area are the careful identification of all bearings received, a preliminary evaluation of bearing condition, and the determination of required processing. The following functions are performed during induction and prescreening:

- Performing the receiving functions for the bearing processing shop.
- Providing limited storage space for accumulation of bearings.
- Establishing and controlling the efficient work loading of the processing shop.
- Rejecting bearings that are beyond economical repair (i.e., bearings with gross damage).
- Precleaning bearings as necessary for identification and screening.
- Segregating bearings into lots according to P/N and/or special inspection requirements.
- Attaching an appropriate identification tab and processing instructions to each bearing lot. Note: Care should be exercised not to mix matched set of bearings or mix components of separable bearings.
- Identifying completely and accurately each bearing lot by the correct P/N and by bearing features from equipment drawings.

- Specifying required lubricant and any special processing and/or precautions that need to be observed.

All used bearings are 100% screened and processed. All new bearings are either sample inspected or 100% inspected.

Personnel handling bearings in this area must satisfy the general requirements of Appendix B-A. In addition, they must have sufficient experience in inspecting and processing bearings accurately to determine processing requirements. Large numbers of bearings of various types and sizes must be screened quickly. Personnel must be familiar with bearing coding and NSN designations, and must be proficient in interpreting drawings. Personnel must also use anti-perspirant hand cream and/or hand gloves when working with the bearing.

Work Area #2 - Cleaning

Bearings must be cleaned before an inspection can be effective. Since the Bearing Shop handles both new and used bearings, the cleaning facilities are quite complex. Individual bearings vary widely in size and type/amount of contamination present (grease and oil are possible lubricants that would need to be removed). The same bearing, depending on its condition when received, may be processed through a variety of cleaning sequences.

Work Area #2 has two separate wash line facilities on parallel lines. One is for new bearings, and one, for used bearings. Temperature and humidity control are not required in the cleaning area, but dust (dirt) control and good ventilation should be maintained. The cleaning area must satisfy the requirements of MIL-B-197 [1]*. The cleaning area is open to the general traffic flow of the building and separated from the primary inspection/examination areas of the Shop. Smoking, eating and drinking are not permitted in this area.

New or used bearings enter the appropriate wash line; the wash lines are conveyor-track arrangements, and bearings are processed in metal trays. The first step in either wash line is to demagnetize the bearings. Demagnetizers (AC type with roller conveyor track, Model SPL-3534 D) remove residual magnetism, which attracts steel chips and contamination particles, prior to cleaning. A gaussmeter, located in the cleaning area, monitors bearings. Demagnetism is also conducted after buffing/polishing and at other times during bearing processing when the gaussmeter indicates it to be necessary. (A maximum of 5 gauss residual magnetism is permitted for large bearings, and 2 gauss, for small bearings of 2-inch outer diameter and smaller.)

Used Bearings

Heavily contaminated bearings are precleaned by spraying solvent (P-D-680 Stoddard Solvent) [2] under pressure to remove most of the heavy deposits. The solvent should be dumped daily. This spraying takes place in the

*Numbers in brackets indicate references at the end of this Appendix.

wash-tank (Auto-Hydro) in the used bearing line. The bearings then proceed through a series of wash/rinse/soak tanks as dictated by bearing condition. The following paragraphs describe the remaining used-bearing cleaning line.

- Tank (1) - Hot Oil Soak (VV-L-800) - Heavy greases and soft-trim hot-dip preservatives can be effectively removed by soaking the bearing in hot oil. Hot oil soak is particularly effective in softening grease deposits prior to an agitated solvent rinse. VV-L-800 preservative oil [3] is used because of its low viscosity and its preservative and water-displacing properties. The tank is heated. Hot oil is the only approved soak solution for nonremovable seal-type bearings.

  A soak process often softens greases, preservative compounds, carbon residues, and adhering foreign matter. This softening assures easier removal in subsequent washing operations. Soak time varies with bearing condition. Agitation is employed.

- Tank (2) - Varsol Rinse (P-D-680) - Light greases, preservative coatings, or oils may be removed by solvents conforming to Federal Specification P-D-680, Type I, [2]. Solvent shall be used only at room temperature, since it has a minimum flash point of 100°F. The solvent shall be continuously filtered to 10 microns.

  A rinse process should follow every soak step during the cleaning operation. The rinse is necessary to remove residual cleaning material. Rinse time is approximately 5-10 minutes and agitation is employed.

- Tank (3) - Trichlorethylene Wash - This step removes certain contamination still on the bearings. Most hydrocarbons are dissolved. This tank is heated and agitated.

- Tank (4) - Carbon Remover (MIL-C-14460) - This tank is agitated.

- Tank (5) - H_2O Rinse - This tank provides neutralization of carbon remover.

- Tank (6) - Houghton Rust Veto 4212 - This tank contains water-displacing oil.

At this point, the used bearings are sent to the spray booth on the new bearing clean line. A spray rinse with P-D-680 is performed. An ultrasonic-small bearing-cleaner is shown in the used bearing clean line, between tanks (6) and (7). Tank (7) is another P-D-680 rinse for the ultrasonically cleaned bearings. At this point the used bearing clean line joins the new bearing clean line before entering the next work area.

New Bearings

New bearings are cleaned in a separate cleaning line in work area #2. There are six tanks appearing in the new bearing clean line. Tank #1 provides a hot oil soak. An auto-hydro wash station, between tanks #1 and #2, performs the same function as in the used bearing line. Tank #2 is a cleanser (trichlorethylene) tank. The spray booth mentioned in the used tanks 3, 4, 5, 6 are all P-D-680 rinse tanks only one or two operated at a time. The bearing cleaning process is physically located between tanks #5 and #6. After tank #6, the new bearing clean line merges with the used line.

All shielded bearings are subjected to ultrasonic cleaning with cleaning compound P-C-444 in the ultrasonic cleaner.

Although physically located in the work area #3, vapor degreasing will be discussed at this point. Vapor degreasing is a cleaning process used to remove residual oils and soft greases which are completely soluble in the degreasing fluid. The action of vapor degreasing requires the immersion of the bearing in the vapors only and not in the fluid phase. The vapors condense on the cooler bearing surface until it becomes as warm as the vapors. When the metal surface and the vapors reach the same temperature, cleaning activity ceases. Trichlorethylene is the degreasing fluid used. A Freon ultrasonic tank is also available in work area #3 as an addition to the cleaning process.

Work Area #3 - Initial Examination

Both new and used bearings enter the initial examination room (work are #3) via the cleaning conveyor line. The vapor degreaser and Freon ultrasonic cleaner are physically located in this work area #3. This area is a limited-access room separated from the general building traffic flow by door passages. The room should be maintained to class 100,000 requirements of Federal Standard 209 [4], and the air should be maintained at 40% (±5%) relative humidity. Such controls are necessary since bearings are in an unprotected, unpreserved state.

In this room, trained inspectors apply the inspection criteria [2], and bearings are passed or rejected. Visual inspection criteria are given in Table B-1 through B-5 for Group A, B, D and E bearings and for bearing retainers. (Special inspection criteria for Group C, instrument bearings. is omitted because consultation with Reference [5] is required.) For purposes of establishing visual standards, bearing surfaces are defined as:

- Functional (or active) Surfaces. All ball, roller (except corners), and raceway surfaces.
- Non-functional (or inactive) Surfaces. Outer and inner diameter surfaces, roller corners, ring faces, retainer guiding land, flanges.
- Retainer Surfaces. All surfaces, including rivets.

Particular defects and/or conditions of these surfaces are as described in the visual inspection criteria, Tables B-1 through B-5. General visual inspection is accomplished with the unaided eye except where magnification is specified/necessary. It must be noted that the inspection process does not include disassembly of normally nonseparable bearings. Split inner race ball bearings are regularly disassembled in the operation. Most roller bearings encountered are either separable or have cage designs which permit removal of a roller without undue force; removal of one roller permits examination of the double flanged raceway. When angular contact bearings with relieved inner or outer races are encountered, normal practice is to leave the bearing assembled; if disassembly is deemed necessary, the bearing is

TABLE B-1

Visual Inspection Criteria for Group A Powerplant Bearings

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Banding (circumferential)	Acceptable	NA	Acceptable	NA
Blistering See Retainer	NA	NA	NA	NA
Brinelling				
a. False	Acceptable	Same	Same	NA
b. True Ball/Roller Sizes	Max Length / Width	Max Length / Width	Max Length / Width	NA
(1) .5 inch Dia. or less use .040 inch radius scriber	.015 in. / .010 in.	Same	Same	
(2) .5 to 1 inch Dia. use .080 inch radius scriber	.025 in. / .010 in.	Same	Same	
(3) 1 to 1.5 inch Dia. use .120 inch radius scriber	.035 in. / .015 in.	Same	Same	
(4) Over 1.5 inch Dia. use .120 inch radius scriber	.045 in. / .015 in.	NA	Same	

NOTE: Brinelling sufficient to cause roughness when the bearing is rotated shall be cause for rejection.

Condition or Damage	Balls	Rollers	Raceways	Non Functional Surfaces
c. Installation or Removal	Not Acceptable	Same	Same	NA
Burnishing	Discoloration Acceptable	Same	Same	Ring Retainer Guiding Surfaces (1) Discoloration - Acceptable (2) Wear - Not Acceptable
Chatter Manufacturing Defect	Not Acceptable	Same	Same	Not Acceptable on bore, OD, face, retainer guiding surface
Crack	Not Acceptable	Same	Same	Same
Finishing Marks	Acceptable (rms must meet drawing requirements)	Same	Same	Same
Fluting (Electrical arcing)	Not Acceptable	Same	Same	Same
Fracture	Not Acceptable	Same	Same	Same
Fretting Corrosion	NA	NA	NA	Acceptable when removed by buffing or polishing. Dimensions must meet drawing limits.
Frosting	Acceptable if there is no evidence of surface deterioration under 10X mag.	Same	Same	NA
Galling	Not Acceptable	Same	Same	Acceptable if bearing meets dimensional limits. Polishing is permitted.

TABLE B-1 (Cont'd)

Visual Inspection Criteria for Group A Powerplant Bearings (Continued)

Condition or Damage	Functional Surfaces: Balls	Functional Surfaces: Rollers	Functional Surfaces: Raceways	Non Functional Surfaces
Healing	Acceptable if there is no evidence of spalling, cracking.	Same	Same	NA
Heat Discoloration Bearings showing discolorations of blue to gray shall be checked for hardness. Check nonfunctional surfaces only	Drawing Requirement or when not specified R_c 58 min.	Same	Same	Same
Inclusions				
Subsurface	Not detectable	Same	Same	Same
Surface	Not Acceptable	Same	Same	NA
Indentations Grouped by ball/roller dia.	Max Dimension			(1) Bore and OD Surfaces 150mm bore - .125 inch max size Over 150mm bore - .250 inch max size (2) Split Inner Ring Surfaces Acceptable if no high metal extends to raceway.
(1) .5 inch Dia. or less use .040 inch radius scriber	.015 in.	Same	Same	
(2) .5 inch to 1 inch Dia. use .060 inch radius scriber	.025 in.	Same	Same	
(3) 1 inch to 1.5 inch Dia. use .080 inch radius scriber	.035 in.	Same	Same	
(4) Over 1.5 inch Dia. use .120 inch radius scriber	.045 in.	Same	Same	
Lap	NA	Not Acceptable	Same	Same
Peeling (Spalling)	Not Acceptable	Same	Same	NA
Pitting	Max of 3 pits in 1/4 inch circle	Same	Same	NA
(1) Corrosion Ball/Roller Sizes	Max Pit Size	Max Pit Size	Same	Any amount if diameters of pits do not exceed .030 inch and affect less than 1/4 inch area. Three .050 inch diameter pits in any 1/4 inch diameter area. Depth not to exceed .010 inch.
(a) .5 inch dia. or less	.010 (.030" scriber)	.015 (.040" scriber)	Same	
(b) .5 inch to 1 inch dia.	.015 (.040" scriber)	.020 (.050" scriber)	Same	
(c) 1 inch to 1.5 inch dia.	.020 (.050" scriber)	.025 (.060" scriber)	Same	
(d) Over 1.5 inch dia.	.025 (.060" scriber)	.030 (.080" scriber)	Same	
(2) Electrical Arcing	Not Acceptable	Same	Same	Same
Scratches Ball/roller sizes	Max size	Circum / Axial		Acceptable
(1) .5 inch dia. or less	.010 (.030" scriber)	.010 3 / None if felt with .030" scriber	Same	
(2) .5 inch to 1 inch dia.	.015 (.040" scriber)	.015 3 / .040"	Same	
(3) Over 1 inch dia.	.020 (.050" scriber)	.020 4 / .050"	Same	

TABLE B-1 (Cont'd)

Visual Inspection Criteria for Group A Powerplant Bearings (Continued)

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Seizure	Not Acceptable	Same	Same	NA
Skidding	Not Acceptable	Same	Same	NA
Smearing	Not Acceptable	Same	Same	NA
Spalling	Not Acceptable	Same	Same	NA
Staining	Acceptable	Same	Same	Same
Wear	Must meet dimen-	Same	Same	Same
General	sional & radial play Limits			
Roller Ends	NA			
(1) Superficial scratches		Acceptable	NA	NA
(2) Wear	NA	.0005 inch max	NA	NA
(3) Eccentric wear or burnishing	NA	Not Acceptable	NA	NA

TABLE B-2

Visual Inspection Criteria for Group B Airframe and Aircraft Control Bearings

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Banding (circum.)	Acceptable	Same	Same	NA
Blistering	NA	NA	NA	Minor loss of plating acceptable with no evidence of rust
Brinelling			Brinelling sufficient to cause roughness when bearing is rotated is unacceptable	
a. False	Slight reddish color acceptable	Same	Acceptable if not felt with following scribers	NA
Ball/roller size up to .5 inch dia.	Slight reddish color acceptable	Same	.040 inch	
.5 to 1 inch dia.	Slight reddish color acceptable	Same	.060 inch	
over 1 inch dia.	Slight reddish color acceptable	Same	.080 inch	
b. True	Slight brinelling is acceptable	Same	Slight brinelling is acceptable if the bearing is not rough to rotate	NA
Ball/roller size up to .5 inch dia.	Slight brinelling is acceptable	Same	Slight brinelling is acceptable if the bearing is not rough to rotate	
.5 to 1 inch dia.	Slight brinelling is acceptable	Same	Slight brinelling is acceptable if the bearing is not rough to rotate	
over 1 inch dia.	Slight brinelling is acceptable	Same	Slight brinelling is acceptable if the bearing is not rough to rotate	
c. Installation/ Removal	Acceptable unless bearing is rough when rotated	Same	Same	NA
Burnishing	NA	NA	NA	NA
Chatter (manufacturing defect)	NA	NA	Not acceptable if bearing is rough when rotated	Not acceptable if OD, bore, or face finish is out of tolerance
Crack	Not Acceptable	Same	Same	Same
Finishing Marks	Acceptable unless bearing is rough when rotated	Same	Same	Acceptable
Fluting (Electrical Arcing)	Not Acceptable	Same	Same	Same
Fracture	Not Acceptable	Same	Same	Same
Fretting Corrosion	NA	NA	NA	Acceptable when removed by buffing/ polishing. Dimensions must be within drawing limits.
Frosting	NA	NA	NA	NA
Galling	Acceptable unless bearing is rough when rotated	Same	Same	Acceptable when high spots are stoned smooth

TABLE B-2 (Cont'd)

Visual Inspection Criteria for Group B Airframe and Aircraft Control Bearings (Continued)

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Healing	Acceptable if there is no evidence of spalling or cracking	Same	Same	NA
Heat Discoloration	Unless specifically designed for high temperature applications, indications of heat discoloration is unacceptable	Same	Same	Same
Inclusions				
Subsurface	Not Detectable	Same	Same	Same
Surface	Not Acceptable	Same	Same	Acceptable if not in an area that would cause cracking
Indentations (Ball/Roller sizes)	Max.Dimension			
.25 inch Dia. or less	.015 (.040"radius scribers)	NA	Same as Ball/Roller	Bore and OD surfaces
.25-.5 inch Dia.	.020 (.050"radius scribers)	.025"(.060" radius scriber)	Same as Ball/Roller	150mm bore - .200 inch max size
.5-1 inch Dia.	.030 (.080"radius scriber)	.040 (.120"radius scriber)	Same as Ball/roller	Over 150mm bore - .400 inch max size
Lap	NA	Not Acceptable	Same	Same
Peeling (Spalling)	Not Acceptable	Same	Same	NA
Pitting				
(1) Corrosion				Acceptable when removed by buffing/polishing. Dimensions must be within drawing limits.
Ball/Roller Sizes	Max.Pit Size	Max. Pit Size	Max. Pit Size	
.25 inch Dia. or less	.015 (.040"radius scriber)	NA	Same as Ball/Roller	
.25-.5 inch Dia.	.020 (.060"radius scriber)	.025"(.060" radius scriber)		
.5-1 inch Dia.	.030 (.080"radius scriber)	.035 (.080"radius scriber)	Same as Ball/Roller	
(2) Electrical (Arcing)	Not Acceptable	Same	Same	Same
Scratches				
Ball/Roller Sizes	Max.Size	Max.Size	Same as Ball/Roller	Any Amount
.25 inch Dia. or less	.015 (.040"radius scriber)			
.25-.5 inch Dia.	.020 (.050"radius scriber)	.025 (.060"radius scriber)	Same as Ball/Roller	
.5-1 inch Dia.	.030 (.080"radius scriber)	.035 (.080"radius scriber)	Same as Ball/Roller	
Seizure	Not Acceptable	Same	Same	NA
Skidding	Acceptable unless surface distress is noted	Same	Same	NA
Smearing	Not Acceptable	Light marks acceptable .080" radius scriber	Same	NA
Spalling	Not Acceptable	Same	Same	NA
Staining	Acceptable	Same	Same	Same
Wear	Must meet dimensional limits	Same	Same	Same
Roller Ends				
(1) Superficial scratches	NA	Acceptable	NA	NA
(2) Wear	NA	.005 inch max.	NA	NA

TABLE B-3

Visual Inspection Criteria for Group D Rotating Electrical Bearings

Condition or Damage	Functional Surfaces: Balls	Functional Surfaces: Rollers (NA)	Functional Surfaces: Raceways	Non Functional Surfaces
Banding (circumferential)	Not Acceptable	NA	Not Acceptable	NA
Blistering (see retainer, Table 7-6)	NA	NA	NA	NA
Brinelling				
(a) False	If reddish color, not acceptable	NA	Not Acceptable	NA
(b) True	Not Acceptable	NA	Not Acceptable	NA
(c) Installation/ Removal	Not Acceptable	NA	Not Acceptable	NA
Burnishing	Discoloration is acceptable	NA	Discoloration is acceptable	Ring retainer guiding surface (1) Discoloration - Acceptable (2) Wear - Not Acceptable
Chattering (Manufacturing defect)	NA	NA	Not Acceptable	Not acceptable on OD, bore, or face surfaces
Crack	Not Acceptable	NA	Not Acceptable	Same
Finishing Marks	Acceptable (rms must meet drawing requirements)	NA	Acceptable (rms must meet drawing requirements)	Same
Fluting (Electrical Arcing)	Not Acceptable	NA	Not Acceptable	Same
Fracture	Not Acceptable	NA	Not Acceptable	Same
Fretting Corrosion	NA	NA	NA	Acceptable when removed by buffing/ polishing. Dimensions must meet drawing limits.
Frosting	Acceptable if no evidence of surface deterioration under 10X mag.	NA	Acceptable if no evidence of surface deterioration under 10X mag.	NA
Galling	Not Acceptable	NA	Not Acceptable	Acceptable when high spots are stoned smooth. Polishing is permitted. Must meet drawing requirements.
Healing	Acceptable if there is no evidence of spalling or cracking.	NA	Same as Ball	NA
Heat Discoloration	Not Acceptable	NA	Not Acceptable	Same
Inclusions				
Subsurface	Not Detectable	NA	Not Detectable	Same
Surface	Not Acceptable	NA	Not Acceptable	Same
Indentations	Not Acceptable	NA	Not Acceptable	NA
Lap	NA	NA	Not Acceptable	Not Acceptable
Peeling (Spalling)	Not Acceptable	NA	Not Acceptable	NA
Pitting				
(1) Corrosion Ball/Roller Sizes	Max. Pit Size			Buffing/polishing permitted. Must meet dimensional limits.
.25 inch Dia. or less	No visible pitting	NA	No visible pitting	
.25-.5 inch Dia.	.010"(.030"scriber)	NA	.015" (.040" radius scriber)	
(2) Electrical Arcing	Not Acceptable	NA	Not Acceptable	Same

TABLE B-3 (Cont'd)

Visual Inspection Criteria for Group D Rotating Electrical Bearings (Continued)

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Scratches				Acceptable
Ball/Roller Sizes	Max.Size		Max.Size	
.25 inch Dia. or less	.010" (.020" radius scriber)	NA	010" (.030" radius scriber)	
.25-.5 inch Dia.	.015" (.030" radius scriber)	NA	.015" (.040" radius scriber)	
Seizure	Not Acceptable	NA	Not Acceptable	NA
Skidding	Not Acceptable	NA	Not Acceptable	NA
Smearing	Not Acceptable	NA	Not Acceptable	NA
Spalling	Not Acceptable	NA	Not Acceptable	NA
Staining	Acceptable	NA	Acceptable	Acceptable
Wear	Must meet drawing requirements	NA	Same as for Ball	Same

TABLE B-4

Visual Inspection Criteria for Group E Helicopter Bearings

Condition or Damage	Functional Surfaces			Non Functional Surfaces
	Balls	Rollers	Raceways	
Banding (circumferential)	Acceptable	NA	Acceptable	NA
Blistering (Plating)	NA	NA	NA	Not Acceptable
Brinelling				
Roughness when bearing is rotated, is unacceptable				
(a) False Ball/Roller Size	If reddish color, not acceptable	Same	Acceptable if not felt with following scriber	NA
up to .5 inch dia.	If reddish color not acceptable	Same	.030 inch	
.5 to 1 inch dia.	If reddish color not acceptable	Same	.040 inch	
1 to 1.5 inch dia.	If reddish color not acceptable	Same	.050 inch	
Over 1.5 inch dia.	If reddish color not acceptable	Same	.060 inch	
(b) True Ball/Roller Sizes up to .5 inch dia. .5 to 1 inch dia. 1 to 1.5 inch dia. Over 1.5 inch dia.	Any evidence of permanent deformation is not acceptable	Same	Same	NA
(c) Installation/ Removal	Not Acceptable	Same	Same	NA
Burnishing	Discoloration is acceptable	Same	Same	Ring retaining guiding surface (1) Discoloration - acceptable (2) Wear - unacceptable
Chatter (Manufacturing Defect)	NA	NA	Not Acceptable	Not acceptable on bore, OD, face, or retainer guiding surface
Crack	Not Acceptable	Same	Same	Same
Finishing Marks	Acceptable (rms must meet drawing requirements)	Same	Same	Same
Fluting (Electrical Arcing)	Not Acceptable	Same	Same	Same
Fracture	Not Acceptable	Same	Same	Same
Fretting Corrosion	NA	NA	NA	Acceptable when removed by buffing/ polishing. Dimensions must be within drawing limits.
Frosting	Acceptable if no evidence of surface deterioration under 10X mag.	Same	Same	NA
Galling	Not Acceptable	Same	Same	Acceptable if bearing meets dimensional limits. Polishing permitted.

TABLE B-4 (Cont'd)

Visual Inspection Criteria for Group E Helicopter Bearings (Continued)

Condition or Damage	Functional Surfaces: Balls	Functional Surfaces: Rollers	Functional Surfaces: Raceways	Non Functional Surfaces
Healing	Acceptable if there is no evidence of spalling or cracking.	Same	Same	NA
Heat Discoloration				
Bearings discolored blue to gray check hardness	Drawing Requirements or when not specified. Rc 58 min	Same	Same	Same
Check Nonfunctional Surfaces Only				
Inclusions				
Subsurface	Not Detectable	Same	Same	Same
Surface	Not Acceptable	Same	Same	Acceptable if not in an area that would cause cracking.
Indentations	Max.Dimension			
Ball/Roller Sizes				
.5 inch dia. or less	.015 (.040" radius scriber)	.020 (.050" radius scriber)	Same	(1) Bore and OD Surfaces 150 mm bore- .150 inch max. size Over 150 mm bore- .300 inch max. size (2) Split inner ring surfaces acceptable if no high metal extends to raceway
.5 inch to 1 inch dia.	.025 (.060" radius scriber)	.030 (.080" radius scriber)	Same	
1 inch to 1.5 inch dia.	.035 (.080" radius scriber)	.040 (.100" radius scriber)	Same	
Over 1.5 inch dia.	.045 (.120" radius scriber)	.050 (.120" radius scriber)	Same	
Lap	NA	Not Acceptable	Same	Same
Peeling (Spalling)	Not Acceptable	Same	Same	NA
Pitting				
Ball/Roller Sizes				
(1) Corrosion	Max. Pit Size	Max. Pit Size	Max. Pit Size	Any amount if diameter of pits do not exceed .035 inch and affect less than 1/4 inch area. Three .060 inch diameter pits in any 1/4 inch diameter area. Depth not to exceed .015 inch.
.5 inch dia. or less	.010 (.030" radius scriber)	.015 (.040" radius scriber)	Same	
.5 inch to 1 inch dia.	.020 (.050" radius scriber)	.025 (.060" radius scriber)	Same	
1 inch to 1.5 inch dia.	.025 (.060" radius scriber)	.030 (.080" radius scriber)	Same	
Over 1.5 inch dia.	.030 (.080" radius scriber)	.035 (.100" radius scriber)	Same	
(2) Electrical (Arcing)	Not Acceptable	Same	Same	Same
Scratches				
Ball/Roller Sizes	Max.Size	Circum / Axial	Same	Acceptable
.5 inch dia or less	.010"	.025"(4) / None if felt with .040" radius scriber		
.5 inch to 1 inch dia.	.020"	.020"(4) / .050" "		
1 inch to 1.5 inch dia.	.025"	.025"(5) / .030" "		
Over 1.5 inch dia.	.030"	.030"(5) / .080" "		
Seizure	Not Acceptable	Same	Same	NA
Skidding	Not Acceptable	Same	Same	NA
Smearing	Not Acceptable	Same	Same	NA
Spalling	Not Acceptable	Same	Same	NA
Staining	Acceptable	Same	Same	Same
Wear	Must meet dimensional limits	Same	Same	Same
Roller Ends				
(1) Superficial Scratches	NA	Acceptable	NA	NA
(2) Wear	NA	.001 inch max.	NA	NA

TABLE B-5

Visual Inspection Criteria for Bearing Retainers

Condition or Damage	Limit
Bent (Out-of-round)	Not Acceptable
Blistering of Plating	Silver Plating - Not Acceptable Lead Plating - Acceptable
Burrs (raised metal)	Not Acceptable - Stone off burrs then inspect to limits for indentations and nicks.
Chips	Not Acceptable
Corrosion	Not Acceptable
Cracks (in webs and in the roller retaining tangs)	Not Acceptable. Certain crack prone bearings will require 30X mag. for crack detection. Use high power magnification as directed by engineering. (See figures 7-52 through 7-54)
Delamination (Phenolic)	Not Acceptable (see figure 7-50)
Flaking of Plating (see Blistering)	
Heat Discoloration	Discoloration resulting from hot heading operation of rivets shall not extend more than .050 inch from edge of rivet head.
Imbedded Particles	Random particles are acceptable. Imbedded particles that have caused wear, scoring to the ring land surface, is not acceptable.
Indentations (Nicks)	
Ball/Roller Sizes	
Non Functional Surfaces	
Less than .5 inch Dia.	Larger than 1/16 inch - Not Acceptable
Over .5 inch Dia.	Larger than 1/8 inch - Not Acceptable
Functional Surfaces	
Less than .5 inch Dia.	Larger than 1/32 inch - Not Acceptable
Over .5 inch Dia.	Larger than 1/16 inch - Not Acceptable
Mismatch	(See figure 7-55)
(1) Circumferential	Two-piece retainers .004 inch max.
(2) Radial	Two-piece retainers .004 inch max.
Overheating	Not Acceptable
Out-of-Round	Any evidence of restriction of movement of the rolling elements is not acceptable.
Peeling of Plating	Silver Plating - Not Acceptable Lead Plating - Acceptable
Porosity	Not Acceptable
Retention (Ball/Roller)	Non-separable retainer with wear or improper staking retention that allows rolling element to drop free from the retainer is not acceptable.
Rivets	Staking impressions that break over any edge are not acceptable.
(1) Missing, unheaded or loose	Not Acceptable (see figures 7-55 and 7-56)
(2) Non-Uniformity of heads on either side of retainer	Not Acceptable
(3) Rivet hole not completely covered by the rivet head	Not Acceptable
(4) Flat spots on conical/spherical heads	Acceptable
(5) Unseated rivet heads	Not Acceptable
(6) Cracks or Splits	Not Acceptable
(7) Heat Discoloration	Acceptable
(8) Loose metal and burrs on rivet heads	Not Acceptable
Spalling (Ball/Roller Pocket)	Not Acceptable
Staining (tarnish)	Acceptable
Wear (Base Metal Exposed)	(see figure 7-57)
Main Engine Shaft Bearings	
Ball/Roller Pocket	
Up to 1/2" Diameter	Up to 1/16" Band
Over 1/2" Diameter	Up to 1/8" Band
Land Surfaces	Not Acceptable (see figure 7-49)

heated in an oven, then the inner ring is cooled with dry ice. Conrad bearings with riveted cages are never disassembled for inspection. In the visual inspection area, inspectors handle the washing and drying within the area, the bearing disassembly to the extent possible, the visual examination (under 7-power magnification when required), and the probing of visible defects with styli. "Feel" inspection (i.e., bearings are rotated by hand or with the inner ring rotated by a motor driven rubber plug) is performed.

A special cleaning station for instrument bearings and special environmental (laminar flow) work benches are utilized for instrument bearing inspection.

Two MTI BDI 100's (one for ball bearings and one for roller bearings) are available, but currently not utilized. Although, original comparisons between manual and BDI-100 inspection results are excellent, the ad hoc modification in the fixturing arrangements seems to have adversely affected the BDI-100 performance. Facilities exist for heating and cooling bearing rings for disassembly purposes, and a temperature-controlled oven for short-term bearing storage is available.

Bearings exhibiting any of the following conditions are sent to the buffing/polishing area for possible correction prior to a pass/reject decision:

- Rust or corrosion on external surfaces.
- Fretting corrosion on external surfaces.
- Stains (other than oil stains) or tarnishes on bearings surfaces that interface with visual inspection.
- Measurable films or coatings still remaining on bearing surfaces after cleaning process.
- Superficial rust or corrosion on active bearing surfaces.

Personnel inspecting bearings in this area must satisfy the general requirements of Appendix B-A. Hand gloves shall be worn by personnel inspecting bearings. In addition, personnel must have at least five years of experience and a background with bearings and their applications. Personnel

assigned responsibilities for the acceptance/rejection of bearings shall have successfully completed a special course on bearing theory and defect analysis and shall have a valid license/stamp.

Work Area #4 - Buffing/Polishing

This area is connected to work area #3 by a closed doorway and an Air Lock pass-thru for bearing handling. Bearing needing buffing/polishing come from the initial examination room. No particular environmental conditions are imposed in this area other than for employee comfort. Buffing/polishing operation are confined to this room only.

Buffing and polishing are limited to metal removal within the dimensional limits of the bearing being processed. The following definitions apply:

- Buffing - A refining operation with buffing compound on soft, flexible cloth or felt wheels or buffs to remove superficial scratches, stains, tarnishes. Buffing produces a surface that is semi-bright, with no pronounced line effect, and it removes very little metal.
- Polishing - An abrading operation with coarse abrasive on hard-face wheels or buffs made of cloth, felt, or leather for removal of sufficient metal to remove tool marks, scratches, pits, and other surface imperfections. A definite coarse line pattern remains after the polishing operation.

The CCAD facility uses soft carbon and soft wire brushes with an oil-pumice medium. Buffing/polishing of rolling elements is not performed.

Buffed/polished bearings require nondestructive testing (NDT), demagnetization, and additional cleaning before being returned to the initial examination room (area #3). If these bearings fail to pass the visual inspection a second time, they are rejected - no additional buffing/polishing is done.

Personnel assigned to buff and/or polish bearing surfaces shall meet the requirements of Appendix B-A. Hand gloves must be worn by all personnel. In addition, personnel shall be specially trained and shall hold a buffing and polishing rate.

Work Area #5 - NDT

This are is connected to work area #4 by a closed doorway and is directly open to the cleaning area (area #2) and the Scrap area (area #10). Bearings have undergone buffing/polishing, any bearings suspected of containing defects, and all reballed bearings are subjected to NDT. No particular environmental conditions are imposed in this area other than for employee comfort.

NDT is used to supplement visual and dimensional inspection, to improve bearing life, and to preclude premature failure due to defects such as cracks, seams, laps, inclusions, etc. Defective bearings can be detected, and many component failures can be prevented.

Work area #5 contains a magnetic particle inspection booth (Magnaflux Inspection Unit MDL - DRA 60) and a penetrant inspection booth (Fluorescent Penetrant Unit TY Magnaflux Type ZA-37). Unit MDL-DRA 60 performs material inspection covered by Specification MIL-I-6868, and is used primarily on integral gear-type bearings. The Fluorescent Penetrant unit, performs inspection covered by MIL-1-6866.

Two tanks in this area contain Solvent P-D-680. Buffed/polished and NDT inspected bearings are cleaned in these tanks and then sent to the spray booth in the new bearing washline. At that time, such bearings undergo visual inspection for a second time. A third tank in work area #5 contains Hot Oil/Corrosion Preventive Compound (MIL-C-11796) for long-time storage. Bearings having been rejected at various points in the Bearing Shop but considered repairable are preserved here, packaged, and sent to ASTORS. There is also a spray booth in this area but is not ordinarily utilized.

All bearings undergoing magnetic particle inspection must be demagnetized before recleaning and reinspection.

Work Areas #6, #7, and #8 - Class 100 Clean Room

A Class 100 Clean Room is connected to work area #3 by an Air Lock pass-thru for handling bearings. This Clean Room is a controlled space containing:

- Work area #6 - Final Cleaning
- Work area #7 - Dimensional Check/Inspection
- Work area #8 - Preservation/Lubrication.

The Clean Room is a horizontal laminar flow room satisfying the requirements of Reference [4]. Personnel enter the room through a double-door air-shower arrangement. Special clothing (hood, suit, boots and gloves) is required to maintain required levels of cleanliness. Only bearings which have successfully passed the visual inspection of work area #3 are passed through to this area.

The air supplied to the Clean Room is conditioned, filtered and circulated as required [4]. Although temperature of 68°F (±5°F) is the standard temperature for calibration and gaging operations, the CCAD room is maintained at 72°F (±1°F) which is more suitable for personnel comfort. All dimensional measurements taken are corrected to the standard gaging temperature. Air in the Clean Room is maintained at 40% (±5%) relative humidity with a positive pressure of 0.45 H_2O above ambient

- Work Area #6

  Bearings enter the Class 100 Clean Room in work area #6 - Final Cleaning. An ultrasonic cleaner is available should additional bearing cleaning be necessary prior to dimensional inspection. Bearing washing is also performed (Freon vapor rinse) after dimensional inspection and prior to lubrication/preservation of the bearings. A DOW-CLEEN apparatus exists in this area, but it is not currently used.

- Work Area #7

  Adjacent to the Final Clean Area is work area #7 - Dimensional Check/Inspection. Gaging of bearings is conducted with gaging techniques that include mechanical, optical, air, and electronic principles.

Bearings are generally checked for bore and O.D. size, radial clearance and axial end play, face flushness, and contact angle, if required. Rolling elements may be replaced in separable bearings. Precision gaging equipment is available as follows:

- Gage Blocks - Comparative-type measurements are generally made in the Bearing Shop. Gage Blocks are the standards for equipment calibration and setup for any precision measurement.
- Inner Diameter (bore) gaging - Bores of bearings up to a few inches in diameter are checked on Sheffield air gages on a go-no-go basis. There are several of these units, utilizing calibrated gaging spindles. Larger bore bearings are measured on a Cordax measuring machine with digital readout. This is an electronic comparator-type measurement. There is also a Bendix unit for measuring bores only. Bore equipment is arranged for two-point measurement. At least three readings, approximately 120 degrees apart, should be made - this is not the current practice. Also, checks for out-of-roundness or taper should be conducted, but such checks are not presently done.
- Outside Diameter Gaging - O.D. measurements are made in the same manner as are bore measurements and the same comments apply.
- Radial Clearance Gaging - There are two gages for measuring radial clearance; bearing size determines which is used. These gages are supplied with sufficient bore plugs to handle the bearings processed. Readout is by dial indicator.
- Axial End Play Gaging - There are two gages for measuring end play; they differ in size and readout is by dial indicator.
- Face Flushness Gaging - One large gage is available for measuring face flushness. Its use is intended for large bearings only, with minimum load of approximately 50 pounds. There is no provision for correcting incorrect face flushness with the facility.
- Contact Angle Gaging - There are three manual angular contact gages, all for the same approximate bearing size range.

- Ball and Roller Classifying Equipment - A ball measuring unit is located in the Clean Room to permit checking of ball diameters and matching of balls in a complement. The same equipment with different fixturing also measures roller diameters (at the center of the roller). There are masters on hand for various ball and roller sizes.

In addition, the following capabilities exist in work area #7:

- Surface Finish - Surface finish may be read by an analyzer which has both a dial readout and a chart recorder. Features such as shape, height, and spacing of irregularities and surface profiles can be determined.

- Indentation Hardness - A Rockwell hardness tester is available, but it is generally only used when bearings indicate possible overheating.

- Waviness Gage - An SKF waviness gage is available but is not currently used. A lack of fixturing to permit installation of bearings on the gage was cited as the reason for its lack of use.

- Optical Comparators - Two optical comparators are used primarily in examining gear tooth profiles.

- Environmental Benches - Two laminar flow environmental benches exist for the handling of miniature/instrument bearings. One large environmental booth is available but is not utilized.

Table B-6, a list of equipment identified on the CCAD Bearing Shop Inventory List as supplied to MTI.

Personnel to dimensionally inspect bearings shall meet the requirements of Appendix A-A. In addition it is absolutely necessary that they have a thorough understanding of gaging techniques including mechanical, optical, air, and electronic principles. Personnel assigned responsibilities for dimensional inspections that result in the acceptance/rejection of bearings shall have successfully completed a course on metrology and shall possess a valid certificate/stamp.

TABLE B-6

Equipment	Quantity	Serial Number
Optical Contour Projection Comparator (10 in.) MDL BL-10	1	0000043932
Optical Contour Projector Model XS/N DL2D-1001	1	0000043549
Elec. Miniature Radial Play Measuring Machine P/N 60547984	1	0000043928
Bendix Radial Play Gage P/N 60109980	1	0000045695
Wilson Instr. Vert. Hardness Testor MDL 3JR	1	0000032911
Bearing Flush Measuring Machine - TY17 MDL 70500371	1	663502401D
Bearing Measuring Machine P/N 60517980	1	6635040873
Elect. Comparator Gage	2	DIPEC 08227 66350 0566D
Radial Play Measuring Machine MDL BD-1 00-82-4	1	6635016473
Bendix Radial Inst. Clearance Measuring Machine - MDL 50200-54	1	663503003D
BRANSON Hardness Testor MDL-100	1	6635045322
SKF Bearing Waviness Testor - MDL - MEB53A	1	66350____
Elect. Miniature Radial Play Measuring Machine P/N 51-60547984	1	663503267D
Bendix Radial Int. Clearance Measuring Machine - MDL 850-54	1	663500907D

Equipment	Quantity	Serial Number
Surface Profile Insp. Measuring System MDL - S - 58	1	6635043923
Bendix Ball Classifier Comparator MDL 1020 - YGB	1	6635043924
Bendix Roller Classifier Comparator	1	6635043925
Bendix Bearing Gage MOD 60549686	1	0000043921
Bendix Axial Play Gage MDL 60553190	1	0000043922
Bendix I.D./O.D. Gage MDL - Proficroder	1	0000043927
B & S Measurement Sys. (.200-12.200)	1	0000041182
Cleveland Elct. Gage MDL PA 615 Type PAR-AC	1	0000031287
Bendix Instr. BRG. Gage (10mm-50mm O.D.) MOD 60105874	1	0000043926
Do-All Gage Block Set - Grade AA (86 pcs)	1	0000041602
Surface Plate - Granite Grade A	4	0000041539 0000041540 0000041571 0000041573
Surface Plate - Granite	1	0000041230
Bearing Race Matching Gage P/N 60105086	1	0000045330
Bearing Race Matching Gage System	1	0000045651
Sheffield Electronic Comparator Accutron - Model 712	1	0000001064

- Work Area #8

The final work area (area #8) in the Clean Room is the Preservation/Lubrication area. Bearings that have successfully passed the inspection process are routed to this area. Bearings that are grease-lubricated in service are lubricated with the specified grease. Bearings that are oil-lubricated in service are protected with a preservative coating compatible with the operating oil. If seals or shields have been removed from a bearing during processing, re-installation of the seals and shields is considered a part of the lubrication process.

After final dimensional inspection and final cleaning (if needed), bearings are demagnetized prior to the preservation/lubrication process. Bearings of open-type construction will usually require the application of a preservative film. Sealed and shielded bearings usually are greased with the operating lubricant. Open bearings are oil-lubricated in service from either a central oil supply or a forced oil system. Since an oil film will tend to drain to the lowest point leaving a relatively unprotected metal surface, a heavier protective film is required for open bearings not scheduled for immediate use. Open bearings that are grease-lubricated in service (such as duplex and stack bearing assemblies) are coated with a preservative oil for improved protection during shelf storage. Some bearings are coated with hot dip preservative. All bearings shall be treated with fingerprint neutralizer prior to processing.

Five tanks exist in work area #8 as follows:

- Tank #1 - Finger Print Remover (MIL-C-15074) - Bearings are immersed in a vertically agitated tank for removal of water-soluble residues on external surfaces.
- Tank #2 - Finger Print Remover Neutralizer (P-D-680) - Bearings from tank #1 are rinsed in vertically agitated tank containing Solvent P-D-680 to remove residue from tank #1 immersion.

- Tank #3 - Short-Term Storage Preservative (Hot Oil MIL-C-6529)- Open bearings to be held in local storage for short duration are immersed in hot preservative oil, Specification MIL-C-6529, Type III.
- Tank #4 - Preservative Oil (MIL-L-23699) - Preservation of bearings by immersion in lubricating oil (MIL-L-23699) is performed. The preservative oil is heated.
- Tank #5 - Long-Term Storage (Hot Dip MIL-C-11796) - For indefinite bearing storage times and times generally to exceed 180 days, bearings are protected with a hot dip coating of Specification MIL-C-11796 preservative compound.

The Bearing Shop possesses a closed grease system capable of dispensing several specification greases for bearing lubrication.

The air in this area should conform to Class 100,000 requirements [4], and the relative humidity should not exceed 40% (±5%) at 75°F (+5°F). The air should be filtered/conditioned to remove industrial gases such as SO_2 and H_2S as required [5]. In addition, entry to the area restricted [5] by means of a double door. Static Eliminators should be provided to remove electrostatic charges from plastic materials prior to use. MTI personnel are not convinced that the requirements are being met.

Instrument bearings should be packaged in at least a Class 10,000 environment [5]. Relative humidity shall be held to 40% (±5%) and temperature to 75°F (±5°F).

Personnel in this area should wear lint-free coats or smocks, head and shoe covers, and lint-free gloves. Antiperspirant hand cream can be used in lieu of gloves. MTI personnel did observe that such precautions were being taken.

Work Area #9 - Packaging/Packing

Work Area #9, Packaging/Packing, is connected at one end to the Clean Room by Air Lock pass-thru, and the other end is open to the general traffic flow of the Shop. Preserved bearings from work area #8, packed and sealed in plastic bags, enter the packaging area; packaging is done [1] and includes all final marking.

Work Area #10 - Scrap Area

Work area #10 is located in the open area of the Shop adjacent to the Clean and NDT areas. Rejected bearings are routed to this point for final disposition. Bearings with gross damage (i.e., cracked parts, fatigued raceways. etc.) are scraped. All remaining rejected bearings are divided into two groups: those which cost more than $80, and those which cost less than $80. Thosewhich cost less than $80 are scrapped. Those which cost more and are considered repairable (i.e., minor damage correctable by special reworking, refurbishment, or restoration) are preserved, packaged, and sent to storage in ASTORS. (Hot-oil long-term preservative (MIL-C-11796) is applied in work area #5.)

REFERENCES TO APPENDIX B

1. Military Specification, MIL-B-197F, Bearings, Antifriction; Associated Parts and Subassemblies; Preparation for Delivery of, March 1977.

2. Specification P.D.-680, Solvent, Dry Cleaning.

3. VV-L-800, Lubricating Oil, General Purpose, Preservative, Water Displacing, Low Temperature.

4. Federal Standard, Fed-STD-209, Clean Room and Work Station Requirements, Controlled Environment.

5. Technical Manual, TM 55-1500-322-24, Maintenance of Aeronautical Antifriction Bearings, July 1980.

APPENDIX B-A

GENERAL PERSONNEL REQUIREMENT

Ref. (2) lists the following general personnel requirements for a bearing processing facility. Requirements indicated in the various sections of this Facility discussion write-up are in addition to these. When no personnel requirements are stated for particular work areas, it is assumed that only the requirements of this appendix apply.

Bearing processing involves special skills and training requirements. Some of the skills are as follows:

- Detect defective bearings by visual and microscopic examination.
- Evaluate bearing condition with respect to specialized application requirements.
- Make judgment decisions as to bearing acceptability based on engineering requirements.
- Dimensionally inspect bearings using ultra-precision gaging equipment measuring in millionths of an inch.
- Test bearings for vibration and smoothness characteristics, and determine acceptability for specific applications.
- Perform first article inspection on new bearings for conformance to drawing requirements.

Personnel performing bearing processing should satisfy the following physical requirements:

(1) VISION TESTS - Vision tests shall be performed by an oculist, optometrist or other professionally recognized personnel. Personnel shall be required to pass vision tests at original qualification, and each calendar year thereafter.

Vision Requirements - The following minimum vision requirements shall apply:

a. Distant vision shall equal 20/30 in at least one eye, either uncorrected or corrected.

b. Near vision shall be equal to normal vision, as prescribed by the optical profession, in both eyes, either corrected or uncorrected.

(2) DEXTERITY TESTS - Dexterity tests shall be required for personnel to be assigned to instrument bearing processing. Instrument size bearings include those under 1 inch outer diameter. Personnel to be assigned responsibilities with precision gaging equipment shall be given dexterity tests.

(3) ACIDITY TESTS - Personnel to be assigned to bearing processing shall be tested by the medical department for high acidity levels in perspiration residues. Personnel with a high acidity level will cause severe corrosion damage to bearings and precision gaging equipment.

(4) GENERAL TESTS - Personnel to be assigned to the clean room area shall be tested for compatibility with such confining and highly restrictive work functions. The following undesirable characteristics shall be considered when selecting clean room personnel;

a. Excessive nervousness

b. Chain smoker

c. Severe dermatologic problems

d. Severe allergy problem with excessive sneezing

Finally, the following technical requirements and qualification/operational tests should be satisfied:

(1) TECHNICAL REQUIREMENTS

a. Personnel must know general theory concerning operation of rolling and plain bearings.

b. Personnel must know general theory concerning gaging, operation, practices, and techniques.

c. Personnel must be thoroughly familiar with processing and inspection requirements contained in ref. (2).

d. Personnel must be able to interpret inspection and test indications upon which to base acceptance or rejection of bearings in accordance with this ref. (2), manufacturers drawings, and contractor requirements.

(2) QUALIFICATION EXAMINATIONS - Personnel assigned to the inspection and acceptance areas of the bearing processing facility shall be qualified by examinations. Examinations can be written, or oral, and operational. Examination will include sample bearings with known defects and/or deficiencies that shall be detected and identified by the person being examined. The qualification status of a bearing inspector shall be maintained by a continuous record of satisfactory workmanship. When personnel have been away from this kind of work for more than 1 year they will be requalified in accordance with requirements contained below

Qualification tests - Applicants shall take written or oral tests to cover the following topics:

a. Basic theory of bearings and lubricants including nomenclature.

b. Methods of checking bearing dimensions.

c. Common types of defects and deficiencies causing rejection.

d. Acceptable marks, dimensional variations, and wear limits.

e. Cleaning, lubrication, preserving, packaging, and identification procedures.

Operational Tests - Operational tests shall include sample bearings with acceptable borderline and unacceptable conditions.

Although the above general personnel requirements are documented in ref. (2) and are applicable to bearing processing facilities, MTI is not certain that they are applied/enforced at CCAD.

APPENDIX C

DOCUMENT MEEI-6940

TSARCOM ENGINEERING DIRECTIVE	TED NO. BGEN-0001C	
	DATE 19 Jun 79	PAGE 1 OF 1

TITLE
New Bearings Requiring 100% Inspection,
A System

TOLERANCES
Unless otherwise noted, dimensions are in inches and tolerances are
Fractional . . . . ±1/32
Decimal . . . . ±0.010
Angular . . . . ±1/2°

APPLICABILITY
All bearings annotated in this TED and Processed at CCAD

REFERENCES	DATE
DF, Critical Component Brgs.	12 Apr 79
DF, Critical Engine Brgs.	12 Jun 79

DOCUMENT(S) AFFECTED
N/A

DOCUMENT CHANGE REQUIRED ☐

PURPOSE OR PROBLEM

To provide specific part numbers of new bearings which are considered critical and require 100% inspection.

WRITTEN BY	CHECKED BY	APPROVED BY
W. H. Mahan W. H. MAHAN	W. H. Mahan W. H. MAHAN	for William Haggerty H. L. BULL

A. Processing of new bearings for systems using A/E engine. The following new bearings shall require 100% inspection for critical parameter (O.D., I.D., width, internal clearance, etc.):

204-040-136-7/-9	212-040-143-1	1-300-329-01/02
204-040-270-3/-5	204-040-424-1	1-300-028-01
204-040-135-1	204-040-408-1	1-300-027-01/02
204-040-269-3	1-300-082-01/02	1-300-026-01
205-040-249-1	212-040-466	1-300-408-02
204-040-271-3	204-040-623-1	1-300-406-01
204-040-132-1	204-011-430-1	1-300-407-01
204-040-129-1	540-011-449-3	212-040-210-1
204-040-133-1	204-011-409-1	212-040-144
204-040-725-1/-3	204-040-407-3	212-040-455
204-040-108-3/-5/-7	204-040-406-1	212-040-456
204-040-345-7	1-300-015-02/04	204-040-245-1
205-040-245-1	1-300-176-01/02/03/04	204-040-145-1
204-040-143-1	1-300-119-01/03	205-040-242-1
204-040-310-1	1-300-031-01/03	205-040-246-3
204-040-346-3	1-300-032-01/03	KWB9N
563-040-408-3	1-300-335-01/02	

B. All areas not specifically covered by this TED shall meet or exceed current authorized technical data.

C. This TED is for CCAD use only and shall be routed to Bearing Shop, 5EC2C.

Revision C: Eliminating bearings not considered critical/add other bearings.

MEEI-6941

TSARCOM ENGINEERING DIRECTIVE	TED NO. BGEN-0002B	
	DATE 19 Jun 79	PAGE 1 OF 2

TITLE	TOLERANCES
New Bearings Requiring 100% Inspection, C and D Systems	Unless otherwise noted, dimensions are in inches and tolerances are: Fractional ± 1/32; Decimal ± 0.010; Angular ± 1/2°

APPLICABILITY	REFERENCES	DATE
All bearings annotated in the TED and Processed at CCAD	DF, Critical Component Brgs.	12 Apr 79
DOCUMENT(S) AFFECTED: N/A	DF, Critical Engine Brgs.	12 Jun 79
DOCUMENT CHANGE REQUIRED ☐		

PURPOSE OR PROBLEM

To provide specific part numbers of new bearings which are considered critical and require 100% inspection.

WRITTEN BY	CHECKED BY	APPROVED BY
W. H. MAHAN	W. H. MAHAN	for H. L. BULL

A. Processing of new bearings for systems using C/E engine. The following new bearings shall require 100% inspection for critical parameter (O.D., I.D., width, internal clearance, etc.):

6873915	6852369	369A5180	206-040-033-1
6876008	6876009	369A5192	206-040-130-1
6876005	6871604	369A5194	206-040-131-1
6871502	39590-39520	369A5258	206-040-032-5
6871505	6873916	369A5193	206-040-037-1
6876010	6857852	369A5198-3	206-040-410-1
6876011	6840137	369A5138	206-040-411-1
6871062	6859436	369A5195	206-040-408-1
6873741	6843389	369A5196	206-040-205-1
6875004	6824728	369A5422	206-040-206-1
6870031	6873917	369A5421	206-040-207-1
6877851	L814749-L814710	369A5433	206-040-036-3
6824711	6857853	369A5420	206-040-409-1
6824712	6840535	369A5423	204-011-769-1
A062	6859434	369A5432	206-011-731-1
454787	6857854	369A5363	206-040-339-7
MR1905EJ8Q	6824734	369A5361	206-010-443-1
6876012	6824733	369A5362	
6871508	369A5199-3	206-040-035-7	
6857885	369A5197	206-040-038-1	

REVISION B: Add references and Change to TED

TSARCOM ENGINEERING DIRECTIVE
(CONTINUATION SHEET)

TED NO.
BGEN-0002B

B. All areas not specifically covered by this TED shall meet or exceed current authorized technical data.

C. This TED is for CCAD use only and shall be routed to Bearing Shop, 5EC2C.

TSARCOM ENGINEERING DIRECTIVE	TED NO. BGEN-0003A	
	DATE 19 Jun 79	PAGE 1 OF 2

TITLE

New Bearings Requiring 100% Inspection, B System

TOLERANCES

Unless otherwise noted, dimensions are in inches and tolerances are:
Fractional .... ± 1/32
Decimal .... ± 0.010
Angular .... ± 1/2°

APPLICABILITY

All bearings annotated in this TED and Processed at CCAD

REFERENCES	DATE
DF, Critical Component Brgs.	12 Apr 79
DF, Critical Engine Brgs.	12 Jun 79

DOCUMENT(S) AFFECTED

N/A

DOCUMENT CHANGE REQUIRED ☐

PURPOSE OR PROBLEM

To provide specific part numbers of new bearings which are considered critical and require 100% inspection.

WRITTEN BY	CHECKED BY	APPROVED BY
W. H. MAHAN	W. H. MAHAN	H. L. BULL

A. Processing of new bearings for systems using B/E engine. The following new bearings shall require 100% inspection for critical parameter (O.D., I.D, width, internal clearance, etc.):

2-300-011-02/04	114DS145-1	114DS645-2/4
2-300-037-01/02	114DS162-1	R1912P
2-300-006-02/05	114DS144-1	114DS664-1
2-300-028-01/03	114DS161-1	114DS668-1
2-300-001-02/05	114DS250-1	114DS670-1
2-300-035-01	114DS275-1	114DS662-1
2-300-034-01	114DS243-1	114DS666-2
2-300-004-02/03/04/06	114DS283-1	114DS349-1
114DS542-4	114DS143-1	114DS340-1
114DS667-1	114DS160-1	114DS282-1/2
114DS642-2	114DS256-1	114DS265-1
114DS571-1	114DS252-1	114DS274-1
~~114DS252-1~~	114DS257-1	114DS281-1
114DS549-1	114DS251-1	114DS641-1
114DS548-1	114DS240-2	114DS661-1
114DS550-1	114DS284-1	114DS669-2
114DS545-1	114DS250-1	114DS541-2
114DS576-1	~~114DS275-1~~	114DS640-2
114DS544-1	114DS242-1	114DS665-1
114DS572-1	114DS280-1	114DS258-4/8
114DS543-1	114DS249-1	114DS244-12
114DS574-1	114DS650-1	114DS241-1
114RS308-1	114DS653-1	114DS254-3
114DS240-2	114DS652-1	114DS247-1
114DS262-1	114DS644-2	114DS248-1
114DS262-2	114DS643-1	114DS255-1

TSARCOM ENGINEERING DIRECTIVE (CONTINUATION SHEET)	TED NO. BGEN-0003A
	PAGE 2 OF 2

B. All areas not specifically covered by this TED shall meet or exceed current authorized technical data.

C. This TED is for CCAD use only and shall be routed to Bearing Shop, 5EC2C.

REVISION A: To eliminate duplication (114DS249-1/145-1/647-1). Also, bearings added (P/N 114DS247-1/248-1/255-1).